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ESTIMATED AREA OF DEER HABITAT IN NEW YORK STATE

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ABSTRACT

An estimate of the area of deer habitat in New York in 1959 was derived from data on land type and land use. The figures were compiled for each town and are summarized here by county for each of the three major regions of the State apart from Long Island. They are compared with an earlier estimate for 1940 and show an over-all increase of nearly 10 per cent. Only four counties showed a decrease. The increase is attributed primarily to the retirement of land from agriculture and would have been greater had not some 20 per cent of the retired farmland been taken over by suburban expansion.

Because of its great adaptability, the white-tailed deer will live in almost any habitat affording food and water, shelter and protection from enemies. In New York, deer live on suburban lands within a few miles of the largest cities, in the scattered brush and woodlots of agricultural areas and in the forested wilderness. In fact, except for parcels actually occupied by buildings and other works of man, the entire land area of the State might be considered as potential deer habitat. However, there are areas where the presence of deer is incompatible with activities and land uses that are essential to man. Such areas must be excluded in a practical assessment of the amount of deer habitat in the State.

Knowledge of the amount of deer habitat is needed in order to evaluate variations in population density as well as the results of deer management including harvests by hunting. An estimate, representing the amount of habitat in 1940, was derived from data contained in the 16th Census of the United States (United States Department of Commerce, 1941) and statistics published by the New York State Tax Commission (1942). A more up-to-date estimate, representing conditions in 1959, has been compiled from data from several State and Federal sources. Not only does the latter give the best available picture of the present situation, but comparison of the two indicates trends that are taking place. The data were given in detail by Severinghaus and Sauer (1964). The present paper summarizes and

compares them by county for the three major regions of the State exclusive of Long Island.

In compiling the 1940 estimate, Federal census figures for "total land area", "land in farms", "woodland on farms" and "all other farm lands" were used. First the amount of "land in farms" was deducted from the "total land area". Then the amount of "woodland on farms" (i.e., woodlots and timber tracts including cut-over land and second growth) was added. And the amount of "all other farm lands" (i.e., non-cropland except woodland) was also added. Finally, figures for the area of cities, villages and unincorporated communities and for the area occupied by roads were derived from State Tax Commission data, and these were deducted. In this way a conservative estimate of the amount of deer habitat in each county was computed.

Additional sources of information were available for the 1959 estimate which provided greater accuracy and enabled compilation by towns. However, only county figures are given here. Following are the definition and derivation of the land categories used for this estimate.

Total land area: Land area is defined as dry land and land temporarily under water. It excludes permanent inland lakes, ponds and reservoirs over 40 acres in area and streams over 1/8 mile wide. Data were taken from the Comptroller's special report on municipal affairs (New York State Comptroller, 1961).

Highways: Area of highways includes all State, county and town highways outside cities and incorporated villages including the average right-of-way for these highways. Mileages were taken from a tabulation by the Department of Public Works (New York State Department of Public Works, 1962) and areas were computed by assuming a 60-foot right of way[1] except for the New York State Thruway. Right-of-way figures for the Thruway were obtained from the Thruway Authority.

Cities and incorporated villages: Areas for these were taken from the State Comptroller's special report on municipal affairs (New York State Comptroller, 1961).

Rural households: This category represents the area occupied by all rural households outside the limits of cities and incorporated villages. The number of rural households was derived

[1]In the 1940 estimate, only the width of the roadbed was considered, so each mile of road equaled approximately 2 acres. As a result of including the 60-foot right-of-way in 1959, each mile equaled 7.273 acres.

from the Federal population census of 1960 (United States Bureau of Census, 1961b) by subtracting the number of households for the villages in a town from the total number for that town. However, the census did not give figures for incorporated villages of less than 100,000 inhabitants. In such cases, the average number of persons per household for the town as a whole was calculated, and this was applied to the population of the village to give an estimate of the number of households in the village. The area attributed to rural households was then computed on the basis of 1 acre each.

Woodlands: This category includes all woodlands whether privately or publicly owned. Areas were derived from the Atlas of Forestry in New York (Stout, 1968).

Data for the remaining categories were derived from the 1959 census of agriculture (United States Bureau of Census, 1961a). Following are descriptions of these categories.

Land in farms: This category was defined as consisting "primarily of 'agricultural' land — that is, land used for crops and pasture or grazing. It also includes considerable areas of land not actually under cultivation nor used for pasture or grazing. For example, the entire acreage of woodland and wasteland owned or rented by farm operators is included as land in farms, unless it was being held for non-agricultural purposes or unless the acreage was unusually large."

Farm woodlands: These areas included figures for two types of land, i.e., "woodland pastured" which was defined as "all woodland where livestock were pastured or grazed in 1959" and "woodland not pastured" which was defined as "all woodland not used for pasture or grazing in 1959, including land in operated farms that was placed in the Soil Bank and planted to trees. Unusually large tracts of timberland that were reported as woodland not pastured were excluded from the tabulation of land in farms when it was evident that such land was held primarily for non-agricultural purposes."

Other pasture: This category was defined as "all land other than woodland and cropland that was used only for pasture or grazing in 1959. It includes noncrop, open or brush pasture and cutover or deforested land that has been improved and used for pasture."

Idle land: In the census of agriculture from which the data were taken, this was included as a subdivision of "cropland har-

TABLE 1. AMOUNT OF DEER HABITAT IN THE VARIOUS COUNTIES OF NEW YORK, ACCORDING TO REGION, IN 1959 AND COMPARATIVE DATA FOR 1940

County	Land area (square miles)	Deer habitat		Woodland		Deer habitat in 1940	Change (per cent)
		Square miles	Percentage of land area	Square miles	Percentage of deer habitat		
		Adirondack region					
Clinton	1,059	817.0	77.1	676.9	82.8	763.6	+ 7.0
Essex	1,826	1,720.9	94.2	1,565.5	91.0	1,669.1	+ 3.1
Franklin	1,685	1,467.5	87.1	1,274.2	86.8	1,434.5	+ 2.3
Fulton	497	400.9	80.7	343.0	85.6	382.8	+ 4.7
Hamilton	1,747	1,707.2	97.7	1,707.2	100.0	1,734.4	− 1.6
Herkimer	1,442	1,183.8	82.1	930.5	78.6	1,119.1	+ 5.8
Jefferson	1,293	757.1	58.5	302.2	39.9	637.4	+18.8
Lewis	1,293	1,053.0	81.4	873.0	82.9	1,001.1	+ 5.2
Oneida	1,227	736.8	60.0	444.2	60.3	613.0	+20.2
Oswego	968	707.0	73.0	455.6	64.4	617.7	+14.5
St. Lawrence	2,767	2,161.3	78.1	1,599.2	74.0	2,034.5	+ 6.2
Saratoga	814	602.3	74.0	452.7	75.2	558.7	+ 7.8
Warren	883	837.3	94.8	800.8	95.6	809.8	+ 3.4
Washington	837	507.2	60.6	341.3	67.3	404.3	+25.5
Sub-total	18,338	14,659.3	79.9	11,766.3	80.3	13,780.0	+ 6.4
		Catskill region					
Albany	531	313.3	59.0	148.3	47.3	283.1	+10.7
Columbia	643	381.7	59.4	246.4	64.5	355.4	+17.5
Delaware	1,470	1,111.3	75.6	762.0	68.6	1,002.0	+10.9
Dutchess	816	532.3	65.2	368.6	69.2	509.4	+ 4.5
Greene	653	505.4	77.4	385.9	76.4	500.1	+ 1.1
Montgomery	409	170.5	41.6	75.0	44.0	137.7	+23.8
Orange	829	511.0	61.6	423.8	82.9	479.3	+ 6.6
Otsego	1,013	655.9	64.8	349.4	53.3	530.5	+23.6
Putnam	235	193.1	82.1	161.1	83.4	200.2	− 3.6
Rensselaer	665	447.1	67.2	288.0	64.4	383.6	+16.6
Rockland	178	128.8	72.5	128.8	100.0	145.5	−11.5
Schenectady	209	118.2	56.5	47.2	39.9	104.5	+13.1
Schoharie	625	419.7	67.2	282.7	67.3	315.7	+32.9
Sullivan	986	852.3	86.4	655.3	76.9	785.2	+ 8.5
Ulster	1,143	948.1	82.9	900.9	95.0	911.3	+ 4.0
Sub-total	10,405	7,288.7	70.0	5,223.4	71.7	6,643.5	+ 9.6
		Central and western region					
Allegany	1,048	762.9	72.8	381.9	50.1	668.7	+14.1
Broome	710	471.5	66.5	252.2	53.5	399.3	+18.1
Cattaraugus	1,330	1,015.4	76.3	657.5	64.7	871.2	+16.6
Cayuga	699	289.8	41.5	139.7	48.2	278.4	+ 4.1
Chautauqua	1,080	674.6	62.5	407.0	60.3	597.4	+12.9
Chemung	412	279.6	68.0	170.5	61.0	237.2	+17.9
Chenango	908	629.5	69.3	339.7	54.0	543.8	+15.8
Cortland	502	322.9	64.3	152.0	47.1	282.7	+14.2
Erie	1,054	507.2	48.1	237.8	46.9	498.0	+ 1.9
Genesee	501	202.4	40.4	98.8	48.8	186.6	+ 8.5
Livingston	638	277.1	43.4	100.3	36.2	256.4	+ 8.1
Madison	661	358.5	54.2	179.1	50.0	311.0	+15.3
Monroe	673	250.6	37.3	53.4	21.3	223.1	+12.3
Niagara	533	210.7	39.6	41.7	19.8	120.7	+74.6
Onondaga	792	393.4	49.6	145.0	36.9	295.3	+33.2
Ontario	649	282.7	43.6	120.3	42.6	259.1	+ 9.1
Orleans	396	163.8	41.4	33.9	20.7	126.7	+29.3
Schuyler	331	216.4	65.3	125.6	58.1	190.5	+13.6
Seneca	330	145.7	44.2	41.6	28.5	111.9	+30.2
Steuben	1,408	890.2	63.2	574.4	64.5	755.4	+17.8
Tioga	525	342.2	65.1	195.6	57.2	281.1	+21.7
Tompkins	491	294.3	59.9	164.1	55.7	258.8	+13.8
Wayne	607	247.6	40.9	175.8	71.0	208.6	+18.7
Wyoming	598	289.9	48.5	133.1	45.9	250.5	+15.8
Yates	344	165.0	48.0	100.8	61.1	141.7	+16.4
Sub-total	17,220	9,683.9	56.2	5,021.8	51.9	8,354.1	+15.9
Westchester	435	250.4	57.5	230.9	92.2	286.6	−12.6
Total	46,398	31,882.3	68.7	22,242.4	69.8	29,064.2	+ 9.7

Figure 1. Percentage of total land area in each county considered to have been deer habitat in 1959.

vested." It is the only category of cropland considered as deer habitat because it was land that had been taken out of production.

The amount of deer habitat was computed for each town. First the areas of highways, cities and incorporated villages, rural households and farms were subtracted from the total land area of the town. Then, to the remainder, were added the parts of the farmlands that were considered as deer habitat, i.e., farm woodlands, other pasture and idle land.

Although this procedure was used for most towns, a different treatment was needed with respect to towns having extensive suburban developments around large cities where households represented less than 1 acre. In such cases, the area of rural households based on the 1-acre factor, plus the area in woodlands and farms, often totalled more than the area of the town. For such towns, the area of deer habitat was considered to be the sum of the areas in woodlands, other pasture and idle land. This situation occurred in certain towns in Cayuga, Clinton, Dutchess, Erie, Monroe and Orange Counties.

In Hamilton and Rockland Counties there were so few farms in 1959 that no breakdown of farmland for the various towns was given in the census of agriculture. Therefore, only the area of woodlands was used to represent deer habitat, although data for additional such habitat on farms had been available for 1940.

Also, a minor adjustment was needed when farmlands were listed within the limits of a city or village. In such instances, the associated farm woodlands, other pasture and idle land were considered deer habitat and were added to the total. This occurred for several villages in Chemung County, Oneida in Madison County, Rome in Oneida County and Saratoga Springs in Saratoga County.

Finally, some data were lacking with respect to Indian reservations. For those in Cattaraugus, Franklin, Niagara and Onondaga Counties, this applied only to the area attributable to highways and represented a negligible error. For those in Erie and Genesee Counties, however, the total land area was not available, and the amount of deer habitat was considered to be the sum of the areas in woodlands, other pasture and idle land.

The data for the various counties in 1959, grouped according to the three major regions of the State, are given in Table 1. Westchester County, however, is listed separately because only bowhunting for big game is allowed there. In addition to the amount of deer habitat, the table gives the proportion that was woodland. It also includes comparative total habitat figures for 1940 and the degree of

change that had occurred. The percentage of total land area that is considered deer habitat in each county is shown in Figure 1.

For the State as a whole (apart from Long Island) there was an increase in deer habitat of nearly 10 per cent from 1940 to 1959. Only four counties showed a decrease. The increase very largely reflected the retirement of land from agriculture and was greatest in the central and western region. However, near large urban areas especially, a considerable proportion of the retired farmland has been taken over by suburban expansion. The data indicated that this may have amounted to about 20 per cent on a statewide basis.

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AGE AND GROWTH OF MALE WALLEYES IN SPAWNING RUNS FROM BLACK LAKE, NEW YORK[1]

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ABSTRACT

Walleyes from Black Lake were measured and jaw tagged, and scale samples were taken, on the spawning runs each spring from 1961 to 1964. A sample of 711 males, in which only age groups III to IX were represented, was selected for a study of age and growth. The age III males on the spawning run were faster growing than the males which spawned first at age IV. The maximum length to be expected was calculated to be 17.7 inches. Growth of male walleyes compared well with that reported for other lakes of the northern United States. The data suggest that a negative correlation between year class abundance and growth exists in Black Lake. In years of poor growth the minimum rates of angling success were higher than in years when growth was better.

Black Lake is located in southwestern St. Lawrence County in northern New York. This shallow, fertile, eutrophic lake of about 10,800 acres is considered one of the prime warmwater fishing lakes in the State. The walleye (*Stizostedion vitreum vitreum*) is the primary game fish. Its population is maintained by natural spawning in two major tributaries and possibly on shoals in the lake itself and in intermittent streams. There is no record of stocking except for two experimental plantings of fingerlings, one in 1961 and the other in 1962.

In the early 1950's, a minor tagging study was conducted by regional fish management personnel. However, available resources were too limited to carry on an intensive, long-term study. Due to the recreational and economic value of the Black Lake sport fishery and the interest shown by local businessmen and anglers, another study of the walleye population was undertaken in 1961. This study was designed to obtain information on growth rate, population size, spawning success and catch rate.

Walleyes were measured and jaw tagged, and scale samples were taken, on the spawning run each spring from 1961 to 1964. Voluntary tag returns were tabulated and length-frequency data were graphed each year. Age and growth data for four years were used to furnish further information on the population parameters.

[1]Data for this study were collected by management personnel of Region 4 of the New York State Conservation Department, and the authors wish to thank them, especially William Pearce, Robert Brewer, Thomas Jolliff, Douglas Wilson and Edward Smith. The paper was reviewed by William Pearce, Dr. Richard Noble and Dr. Edward Houde who all made valuable criticisms and suggestions. Thanks are also due Dr. John Forney of Cornell University for assistance with many of the problems encountered.

MATERIALS AND METHODS

Walleyes collected for this study were obtained from two spawning sites, one on the Indian River at Rossie and the other on Fish Creek at Pope Mills. In 1961 the Rossie site was the only one sampled.

The walleye spawning run begins in late March and early April when water temperature reaches approximateily 42° F. In 1961, 1962 and 1963 the fish were collected by blind scapping at night, and in 1964 trap netting and electrofishing were also used.

Blind scapping on the spawning area, using a long-handled dip net, was done after dark. Trap netting was done below the spawning area using 4- and 6-foot nets which were operated for 24 hours each day. Electrofishing in 1964 was done by means of a 110-volt AC back-pack shocker with a wand and trailing electrode.

Fish were measured to the nearest 0.1 inch in total length (with lobes of caudal fin compressed). Scale samples were taken from a point below the lateral line and just ahead of the dorsal fin. Sex was determined by partial stripping.

Scales were obtained from 1,450 male walleyes over the 4-year period, and each year's sample was stratified into half-inch size groups with a random sample of 15 fish being selected for aging according to the method described by Ketchen (1950). This yielded a sample of approximately 180 fish per year and a total of 711 males to be aged. A jewelers press (Butler and Smith, 1953) with 2-inch steel rollers gave consistently good impressions on 0.03-inch-thick cellulose acetate.

The characteristics for annuli determinations described by Carlander and Whitney (1961) were used, and the annuli were marked off on paper strips. These strips were later used to back-calculate the lengths on a nomograph as described by Carlander and Smith (1944).

Scale samples were mixed and the scales read without references to the length or year of collection (Carlander, 1961). Scales were read at least twice, and in some instances as many as five times, until agreement on the number of annuli was reached. The authors read scales together until the technique was perfected. Rereading resulted in nearly the same percentage of agreement, supporting the belief that the same criteria were being used.

BODY-SCALE RELATIONSHIP

Since there were no fish younger than age III in the 711-fish sample, a regression line to determine the intercept for the relationship between scale radius and body length would have been somewhat misleading. However, an intercept point of 2.28 inches was obtained

by Forney (1965) in his study of walleyes in Oneida Lake (N. Y.). This was used for the Black Lake data because of the relative proximity of Black Lake to Oneida Lake and also because the length frequencies were comparable.

TABLE 1. DISTRIBUTION OF AGE-GROUPS AMONG MALE WALLEYES COLLECTED FROM BLACK LAKE, 1961-1964

Year	Number specimens	Age group						
		III	IV	V	VI	VII	VIII	IX
1961	175	36	32	26	41	35	4	1
1962	190	39	21	24	38	43	17	8
1963	175	38	50	22	21	20	22	2
1964	171	14	38	45	20	20	27	7

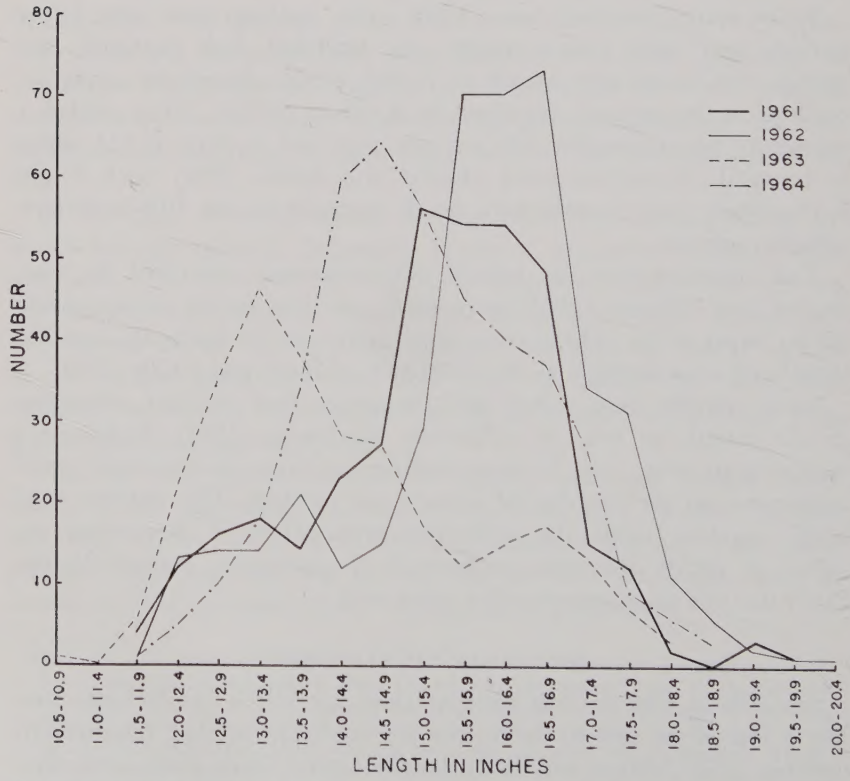

Figure 1. Length-frequency distribution of male walleyes from Black Lake, 1961-1964.

AGE COMPOSITION

The validity of the aging technique used was verified by the pattern of age-group distribution in the samples of a given year class for successive years (Table 1). Furthermore, length-frequency modes moved along at rates consistent with back-calculated growth increments (Figure 1).

Male walleyes captured on the spawning run ranged in age from III to IX in each of the four sampling years. The actual lengths of age III walleyes in each year's collections were greater than the lengths derived by back-calculating from the measurements of age IV fish taken the following year (Table 2). When the same procedure was followed for age IV and V fish, both lengths at age IV were similar. Therefore, it was concluded that the age III males on the spawning run were the faster growing individuals of their year class and that the slower growing males appeared for the first time at age IV.

A Walford line (Walford, 1946) was plotted to give a graphical representation of the ultimate size that might be reached by male walleyes in Black Lake. A line of good fit was calculated for the plotted points by the least squares method (McCarthy, 1957) using the equation

$$Y = a + b\,(X)$$

in which,

Y = length at year N + 1
a = height of regression line above X axis
b = slope of regression line
X = length at year N

The ultimate size was estimated to be 17.7 inches, based on the intersection of that line (Y) with a line (X) drawn at an angle of 45 de-

TABLE 2. COMPARISON OF ACTUAL AND BACK-CALCULATED LENGTHS FOR 3-YEAR-OLD MALE WALLEYES

Year class	Mean length at age III	
	Actual	Back-calculated*
1958	12.6	12.2
1959	12.9	12.2
1960	12.6	12.4
1961	12.9	..

*From lengths recorded for age IV fish.

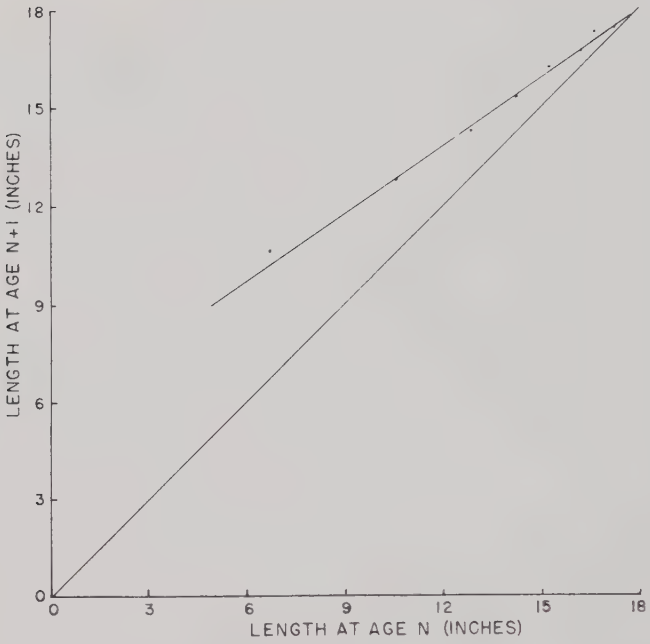

Figure 2. Determination of Walford line for male walleyes from Black Lake.

TABLE 3. CALCULATED MEAN LENGTH AT SUCCESSIVE AGES FOR MALE WALLEYES OF 1953 TO 1961 YEAR CLASSES

Year class	Number specimens	Age								
		I	II	III	IV	V	VI	VII	VIII	IX
1953	12	7.6	11.2	13.3	14.8	15.7	16.5	17.1	17.6	18.2
1954	54	6.9	11.0	13.2	14.6	15.4	16.0	16.5	17.5	18.8*
1955	113	7.2	11.0	13.1	14.4	15.3	15.9	16.4	16.9	17.2
1956	111	7.3	11.2	13.3	14.6	15.5	16.2	16.5	17.1	..
1957	97	6.5	10.2	12.6	14.1	15.3	16.2	16.8	..	..
1958	99	6.1	10.2	12.5	14.0	15.1	16.1	..	..	..
1959	134	6.7	10.1	12.5	13.9	14.8	..	..	..	..
1960	76	6.3	9.9	12.5	13.6	..	..	..	..	..
1961	14	6.5	10.6	12.9	..	..	..	..	..	..
Unweighted mean		6.8	10.6	12.9	14.3	15.3	16.2	16.7	17.3	17.4

*Based on two fish.

grees from zero (Figure 2). This maximum size is in close agreement with the mean length of 17.4 inches recorded for age IX specimens.

GROWTH

After the scales had been aged and lengths back-calculated, the data were put into age categories. The lengths of successive age groups were then determined for the year classes represented (1953 to 1961). For each age group, four years of sampling data were used to determine the mean length attained. There was very good agreement for all the length determinations among the samples.

From a compilation of these data, an unweighted mean length for each age group was calculated (Table 3) for a comparison of growth in Black Lake with that for walleye populations in other lakes. Com-

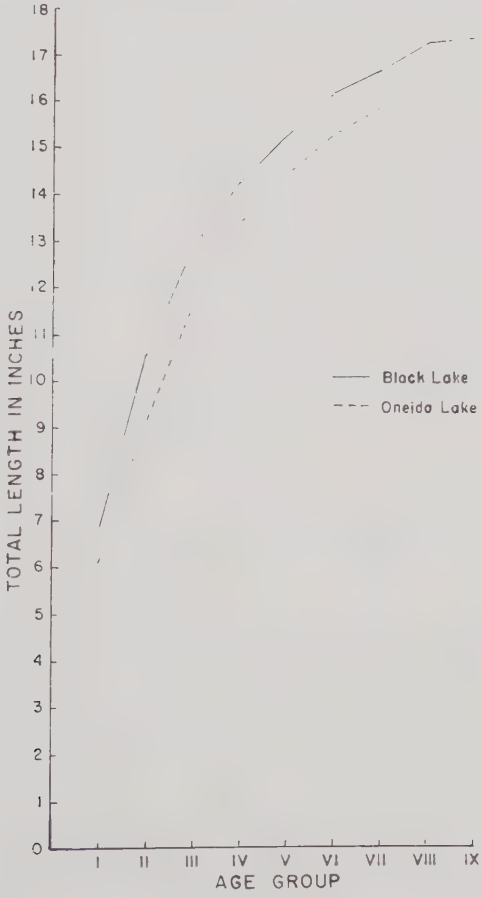

Figure 3. Comparison of growth curves for male walleyes from Black Lake and Oneida Lake.

parison with data for Oneida Lake (Forney, 1965) showed that male walleyes from Black Lake were approximately 1 inch longer in each age group after I (Figure 3). Those in Black Lake grew faster than those in Oneida Lake during their first year of life and then grew at approximately the same rate.

Growth for male walleyes in Black Lake was also compared with that in other waters in the same latitude as reported by Carlander (1953). The Black Lake fish grew faster than those from the Wolf River in Wisconsin, the same as those from Lake Gogebic in Michigan and slower than the ones from Washington County, Wisconsin.

Mean and annual growth increments (Table 4) were derived from the back-calculated lengths. Hile (1941) showed that growth of various year classes during a given period of years could be compared by computing a growth index for each class by adding the annual increments and dividing by the unweighted mean for that class. Increments for fish of age groups III to VII were used. Age groups I and II were not represented in the samples. Age groups VIII and IX were eliminated because these ages were too difficult to determine accurately. Furthermore, Smith and Pycha (1960), working with walleyes in Minnesota, found that growth trends of young and old fish differed from those of other age groups.

Although no population estimates were made, it is evident (Table 1) that the 1955, 1956 and 1959 year classes were most abundant in the samples from 1961 to 1964. The 1955 and 1956 year classes also

TABLE 4. MEAN ANNUAL GROWTH INCREMENTS FOR MALE WALLEYES

Year class	Years subsequent to hatching								
	1	2	3	4	5	6	7	8	9
1953	7.6	3.6	2.1	1.5	0.9	0.8	0.6	0.5	0.6
1954	6.9	4.1	2.2	1.4	0.8	0.6	0.5	1.0	..
1955	7.2	3.8	2.1	1.3	0.9	0.6	0.5	0.5	0.3
1956	7.3	3.9	2.1	1.3	0.9	0.7	0.3	0.6	..
1957	6.5	3.7	2.4	1.5	1.2	0.9	0.6	..	..
1958	6.1	4.1	2.3	1.5	1.1	1.0	..	..	..
1959	6.7	3.4	2.4	1.4	0.9	..	..	..	..
1960	6.3	3.6	2.6	1.1	..	..	..	..	..
1961	6.5	4.1	2.3	..	..	..	..	..	..
Unweighted mean	6.8	3.8	2.3	1.4	1.0	0.8	0.5	0.7	0.5

exhibited the poorest growth (Table 5). These data suggest that a negative correlation between year class abundance and growth exists in Black Lake. More investigation will be needed to determine just what the relationship is. Carlander and Whitney (1961) found slow growth associated with abundant year classes in Clear Lake in Iowa. However, Forney (1965) found the growth of individual year classes in Oneida Lake to be independent with respect to their numerical abundance.

Growth indices were also calculated for male walleyes of age groups III to VII for the years 1959 to 1963 (Table 6). For these age groups growth was greatest in 1961 and 1962.

Forney (1965) showed a relationship between growth and minimum rates of exploitation in Oneida Lake. In years of poor growth, higher rates of exploitation occurred.

For Black Lake the minimum exploitation rates for male walleyes tagged in 1962 and 1963 were calculated. The minimum rate in 1962

Table 5. Growth Indices for Male Walleyes of Year Classes 1953 to 1961

Year class	Growth index
1953	98.3
1954	91.7
1955*	90.0
1956*	88.3
1957	110.0
1958	107.2
1959*	100.0
1960	100.0
1961	100.0

*Strong year class.

Table 6. Annual Growth Indices from 1959 to 1963 for Male Walleyes of Age Groups III to VII

Year	Growth index
1959	96.7
1960	96.7
1961	105.0
1962	105.0
1963	98.3

for fish tagged in 1962 was 5.5 per cent, and that in 1963 for fish tagged in 1963 was 8.3 per cent. In 1963, however, 8.5 per cent of the fish tagged in 1962 were reported, although one would have expected this percentage to have been lower than 5.5 per cent. Since growth was poor in 1963, these data also indicate greater angling success in years of poor growth.

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HERBACEOUS FOOD PREFERENCES OF WHITE-TAILED DEER[1]

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ABSTRACT

A study of the use of herbaceous foods by white-tailed deer was made on a 56.8-acre enclosure on the Partridge Run Game Management Area in Albany County (N.Y.). Twenty ½-milacre plots were selected, and observations were made during the spring in 1957 and 1958 and during the summer in 1955, 1956, 1957 and 1958. The number of deer present on each occasion was known. Data were analyzed in terms of the degree of use in relation to the degree of availability. Preferred and non-preferred species are listed. Notes on use by animals other than deer, in 1959 and 1962 when no deer were present, are included.

Since winter is the most critical period for deer survival, most surveys of deer food have been concerned with winter-browse species. Some research into the summer food habits of white-tailed deer (*Odocoileus virginianus*) have been reported by Palmer (1951), Watts (1964) and Webb (1959). However, these authors also mainly considered woody browse species. Little has been done toward determining the herbaceous food preference of deer. This paper presents data concerning use of these foods at the Partridge Run Game Management Area in the Town of Rensselaerville in Albany County (N.Y.).

METHODS

The work was done in a 56.8-acre deer enclosure on the Area. Twenty plots were surveyed during August in 1955 and 1956, and 25 plots were surveyed during August in 1957, 1958, 1959 and 1962. In addition, 25 plots were surveyed during late May and early June in 1957 and during early June in 1958. For purposes of comparison, only data from the 20 plots that figured in all the surveys were used for this analysis. Deer were present in the enclosure during the surveys in the first four years, but not during those in 1959 and 1962. When they were present, their number and age composition were known.

Square plots, 4 feet 8 inches on a side and representing ½ milacre, were used, and were located astride established deer trails. They were not randomly selected because observations during the previous summer had shown that randomly selected plots probably would show

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SAMPLING DEER RANGE CONDITIONS

County _____ Township _____ Date _____

Designation of area _____ Observer _____

1. Station No. _____

2. Slope: Degree _____ Exposure _____

3. Crown cover: Type _____ Undergrowth: Type _____

Density _____ Density _____

4. Shelter: Relative Quality _____

5. Relative total quantity of browse produced _____

6. Composition of above by species and their current status: _____

Species	Percentage representation in available browse supply	Percentage use by deer of browse produced	Species	Percentage representation in available browse supply	Percentage use by deer of browse produced
Antennaria					
Anemone					
Aster					
Daucus carota					
Hieracium					

Figue 1. Form on which data concerning herbage present and its use by deer were recorded.

little visible evidence of food use. Therefore, for convenience in reducing the amount of time and work required to determine preference, the plots were located selectively to sample use where deer activity was concentrated. Some pilot observations of plot shape were made to determine if any bias in the degree of use could be avoided by sampling long, narrow plots, but there seemed to be no evidence of such bias.

Data were recorded on a standard form (Figure 1). Only the following items were used in the present study.

4. Crown cover: Type and density were recorded according to the symbols described by Anonymous (1944).
6. Relative total quantity of available herbage produced: This was determined by visual estimate, from minimum to maximum, according to a scale of 2, 4, 6, 8 and 10. These values were then considered as units of amount in further computations.
7. Composition of above by species and their current status: All herbaceous species on each plot were inventoried. For each species, its representation in the total herbage present and its use by deer were determined by visual estimate to the nearest percentage in each case.

TABLE 1. COMMON NAMES AND SCIENTIFIC NAMES OF HERBACEOUS PLANTS EATEN BY DEER AND OTHER ANIMALS ON THE STUDY PLOTS

Common Name	Scientific Name
Agrimony	*Agrimonia gryposepala*
Aster	*Aster* spp.
Aster, white wood	*Aster divaricatus*
Avens	*Geum* spp.
Avens, water	*Geum rivale*
Bedstraw	*Galium* spp.
Bluegrass	*Poa* spp.
Bluegrass, Canada	*Poa compressa*
Bugleweed	*Lycopus* spp.
Bugleweed, Virginia	*Lycopus virginicus*
Bulrush	*Scirpus* spp.
Butter-and-eggs	*Linaria vulgaris*
Buttercup	*Ranunculus* spp.
Carrot, wild	*Daucus carota*
Catnip	*Nepeta cataria*
Cinquefoil	*Potentilla* spp.
Cinquefoil, oldfield	*Potentilla canadensis*
Clover	*Trifolium* spp.
Clover, hop	*Trifolium agarium*
Clover, red	*Trifolium pratense*
Daisy, oxeye	*Chrysanthemum leucanthemum*
Dandelion	*Taraxacum officinale*
Dock	*Rumex* spp.
Elecampane	*Inula helenium*
Everlasting, pearly	*Anaphalis margaritacea*
Fern, bracken	*Pteridium aquilinum*
Fern, sensitive	*Onoclea sensibilis*
Fleabane	*Erigeron* spp.
Geranium, wild	*Geranium maculatum*
Goldenrod	*Solidago* spp.
Goldenrod, early	*Solidago juncea*
Goldenrod, giant	*Solidago gigantea*
Goldenrod, grassleaf	*Solidago graminifolia*
Goldenrod, silver	*Solidago bicolor*
Goldenrod, woodland	*Solidago nemoralis*
Goldenrod, wrinkled	*Solidago rugosa*
Hawkweed	*Hieracium* spp.
Horsetail, field	*Equisetum arvense*
Iris, blueflag	*Iris versicolor*
Jack-in-the-pulpit, Indian	*Aresaema tryphyllum*
Jewelweed, spotted	*Impatiens biflora*
Joe-pye weed	*Eupatorium maculatum*
Knotweed	*Polygonum* spp.
Lilac	*Syringa* spp.
Liveforever	*Sedum tryphyllum*
Loosestrife, whorled	*Lysimachia quadrifolia*
Mannagrass, fowl	*Glyceria striata*
Milkwort, purple	*Polygala sanguinea*
Oatgrass, wild	*Danthonia* spp.
Orchid, small purple fringed	*Habenaria psycodes*
Panic grass	*Panicum* spp.
Plantain, blackseed	*Plantago Rugelii*
Plantain, buckhorn	*Plantago lanceolata*
Plantain, common	*Plantago major*
Pussytoes	*Antennaria* spp.
Ragweed	*Ambrosia* spp.
Redtop grass	*Agrostis alba*
Rush	*Juncus* spp.

TABLE 1. (*Continued*)

Common Name	Scientific Name
Saxifrage, swamp	*Saxifraga pennsylvanica*
Sedge	*Carex* spp.
Selfheal	*Prunella vulgaris*
Snakeroot, white	*Eupatorium rugosum*
Sorrel, sheep	*Rumex acetosella*
Sorrel, tall yellow wood	*Oxalis europea*
Sorrel, white wood	*Oxalis acetosella*
Sorrel, wood	*Oxalis* spp.
Speedwell	*Veronica officinalis*
St. John's-wort	*Hypericum* spp.
St. John's-wort, common	*Hypericum perforatum*
Strawberry	*Fragaria virginiana*
Tearthumb, arrow-leaved	*Polygonum sagittatum*
Thistle	*Cirsium* spp.
Timothy	*Phleum pratense*
Tobacco, Indian	*Lobelia inflata*
Vernalgrass, sweet	*Anthoxantum odoratum*
Vetch	*Vicia* spp.
Virgin's bower	*Clematis virginiana*
Wintercress, common	*Barbarea vulgaris*
Yarrow	*Achillea millefolium*

For each plot, the amount available (in units) of each species was calculated by applying its percentage of representation to the value assigned for the relative total quantity of available herbage on that plot. From this, the amount of that species used (i.e., eaten) by deer was calculated by applying the corresponding percentage of use recorded. The sums of these amounts, respectively, for all plots constituted the totals for the species for the whole area.

These totals for the various species were in turn totalled, and the percentage representation for each species over the area as a whole was calculated for the amount available and the amount eaten. Finally, an average percentage eaten for each species and for the area as a whole was derived from the ratio of the amount eaten to the amount available. These figures, in descending order, were considered to reflect the degree of preference by deer.

In 1959 and 1962, when deer were not present in the enclosure, data were recorded concerning the consumption of herbaceous vegetation by other animals. The same form and general procedure were used as during previous years. But no estimates of the abundance of the other animals were made.

The common names and scientific names of the plant species involved are given in Table 1.

FINDINGS

No relation was found between the number of deer present and the use of herbaceous growth (Table 2). The degree of use increased

progressively from 1955 to 1958, corresponding to a progressive increase in amount of herbage available. Cover-type composition of the plots did not change appreciably during this period, so the

Table 2. Use of Herbage in Relation to Number of Deer Present

Date of survey	Herbage			Deer present		Date fawns born
	Available*	Eaten		Adult	Fawn	
		Amount*	Per cent			
August 4, 1955	78.0	0.8758	1.1	4	2	June 1
					1	June 10
August 13-14, 1956	94.0	2.1932	2.3	6	2	May 25
					2	June 25
May 29-June 5, 1957	76.0	0.8536	1.1	6	2	May 25
August 7-9, 1957	106.0	2.7384	2.6	6	4	June 25§
June 3-4, 1958	72.0	0.7276	1.0	6	0	..
August 11-12, 1958	112.0	3.1010	2.8	6	2	July 28
August 3-10, 1959	106.0	0.2366	0.2	..	..	..
July 31-August 2, 1962	88.0	0.4714	0.5	..	..	..

* In units.

§ Applies to the two fawns born after the first survey.

changes in the amount of herbage available were probably normal responses of the vegetation to environmental conditions.

The data concerning availability and use during the August surveys are summarized in Table 3 in which the species (or genera) are arranged in descending order of preference by deer as indicated by the average percentage eaten of the amount available. Since the data for 20 plots were used each year, an herbage production value of 10 for each plot would represent a maximum total production of 800 units for the four years. The recorded figure was 390 units. The average percentage eaten for all species was 2.3, and species ranking above this level were considered preferred. Preferred species which also were rated at 1 per cent or more in availability were early goldenrod, woodland goldenrod, sensitive fern, bracken fern, whorled loosestrife, timothy and wrinkled goldenrod. Non-preferred species having similar availability were redtop grass, hawkweed, selfheal, aster, sheep sorrel, hop clover, grassleaf goldenrod, Canada bluegrass, wild oatgrass, strawberry, oldfield cinquefoil, pussytoes, sedge, bulrush, St. John's-wort, yarrow and white snakeroot. Data on use by other animals in 1962, when deer were not present, indicated light consumption.

TABLE 3. PREFERENCE OF DEER FOR HERBACEOUS PLANTS ON THE STUDY PLOTS DURING AUGUST AS INDICATED BY RELATION OF AMOUNT EATEN TO AMOUNT AVAILABLE, TOGETHER WITH DEGREE OF USE BY OTHER ANIMALS WHEN DEER WERE NOT PRESENT

Species*	Use by deer (1955-1958)						Use by other animals (1962)†
	No. of plots	Herbage available		Herbage eaten		Average eaten§ (per cent)	
		Units	Percent	Units	Percent		
Joe-pye weed	4	1.75	0.4	0.5330	6.0	30.5	..
Early goldenrod	47	32.78	8.4	2.2886	25.7	7.0	0.3
Spotted jewelweed	4	0.78	0.2	0.0462	0.5	5.9	..
Woodland goldenrod	26	10.80	2.8	0.5246	5.9	4.9	..
White wood aster	4	2.56	0.7	0.1166	1.3	4.6	0.8
Giant goldenrod	7	1.58	0.4	0.0700	0.8	4.4	..
Elecampane	7	1.01	0.3	0.0436	0.5	4.3	..
Sensitive fern	4	6.41	1.6	0.2402	2.7	3.8	2.0
Virgin's bower	4	0.70	0.2	0.0220	0.3	3.1	..
Bracken fern	4	6.66	1.7	0.2086	2.4	3.1	..
Whorled loosestrife	27	9.09	2.3	0.2724	3.1	3.0	0.3‡
Goldenrod	6	2.14	0.6	0.0624	0.7	2.9	..
Water avens	5	0.67	0.2	0.0195	0.2	2.9	..
Timothy	39	21.52	5.5	0.5964	6.7	2.8	1.4
Oxeye daisy	26	3.42	0.9	0.0926	1.0	2.7	0.6
Wrinkled goldenrod	28	25.62	6.6	0.6711	7.5	2.6	0.2
Redtop grass	28	7.60	2.0	0.1670	1.9	2.2	0.8
Hawkweed	54	12.24	3.1	0.2606	2.9	2.1	1.0
Buckhorn plantain	8	1.34	0.3	0.0282	0.3	2.1	..
Buttercup	23	2.92	0.8	0.0568	0.6	1.9	0.2
Fleabane	5	0.42	0.1	0.0080	0.1	1.9	..
Agrimony	12	1.68	0.4	0.0300	0.3	1.8	..
Selfheal	31	8.14	2.1	0.1366	1.5	1.7	1.2
Aster	40	13.32	3.4	0.2202	2.5	1.7	0.2
Red clover	2	0.32	0.1	0.0052	0.1	1.6	..
Sheep sorrel	25	3.94	1.0	0.0634	0.7	1.6	0.3
Hop clover	24	4.78	1.2	0.0722	0.8	1.5	0.4
Bluegrass	4	0.88	0.2	0.0128	0.1	1.4	..
Butter-and-eggs	4	0.36	0.1	0.0052	0.1	1.4	..
Grassleaf goldenrod	51	27.28	7.0	0.3810	4.3	1.4	0.3
Wild geranium	19	2.86	0.7	0.0374	0.4	1.3	0.6
Canada bluegrass	33	13.44	3.5	0.1740	2.0	1.3	2.3
Clover	16	1.94	0.5	0.0246	0.3	1.3	1.1
Wild oat grass	64	54.73	14.0	0.6611	7.4	1.2	0.7
Sweet vernalgrass	4	2.92	0.8	0.0326	0.4	1.1	1.2
Strawberry	62	16.37	4.2	0.1822	2.0	1.1	0.8‡
Common wintercress	1	0.16	..	0.0016	..	1.0	..
Wild carrot	7	0.68	0.2	0.0068	0.1	1.0	0.5
Common St. John's-wort	4	0.36	0.1	0.0036	..	1.0	0.4
Oldfield cinquefoil	62	24.70	6.3	0.2340	2.6	0.9	0.3
Pussytoes	28	3.84	1.0	0.0320	0.4	0.8	0.3
Vetch	4	0.24	0.1	0.0020	..	0.8	..
Speedwell	11	1.80	0.5	0.0144	0.2	0.8	..
Common plaintain	4	0.33	0.1	0.0025	..	0.8	..
Fowl mannagrass	3	1.26	0.3	0.0092	0.1	0.7	..
Sedge	30	14.96	3.8	0.1094	1.2	0.7	..
Avens	3	0.34	0.1	0.0024	..	0.7	..
Virginia bugleweed	2	0.46	0.1	0.0030	..	0.6	..
Bulrush	8	5.71	1.5	0.0360	0.4	0.6	..
White wood sorrel	15	1.67	0.4	0.0101	0.1	0.6	..
Bedstraw	7	0.74	0.2	0.0042	0.1	0.6	..

TABLE 3. (*continued*)

Species*	Use by deer (1955-1958)						Use by other animals (1962)†
	No. of plots	Herbage available		Herbage eaten		Average eaten§ (per cent)	
		Units	Per-cent	Units	Per-cent		
St. John's-wort	48	6.06	1.6	0.0276	0.3	0.5	0.5
Panic grass	22	3.48	0.9	0.0151	0.2	0.4	..
Pearly everlasting	4	0.54	0.1	0.0020	..	0.4	..
Field horsetail	4	2.00	0.5	0.0064	0.1	0.3	..
Blueflag iris	4	0.46	0.1	0.0012	..	0.3	..
Liveforever	4	0.42	0.1	0.0010	..	0.2	..
Wood sorrel	11	1.10	0.3	0.0022	..	0.2	..
Yarrow	35	5.14	1.3	0.0072	0.1	0.1	..
White snakeroot	4	6.20	1.6	0.0076	0.1	0.1	5.0
Ragweed	5	0.44	0.1	..	..	..	..
Indian Jack-in-the-pulpit	2	0.38	0.1	..	..	..	..
Thistle	3	0.34	0.1	..	..	..	..
Small purple fringed orchid	1	0.04	..	..	..	..	..
Rush	3	0.30	0.1	..	..	..	..
Indian tobacco	1	0.08	..	..	..	..	..
Bugleweed	3	0.34	0.1	..	..	..	..
Blackseed plantain	2	0.12	..	..	..	..	..
Purple milkwort	2	0.10	..	..	..	..	..
Arrow-leaved tearthumb	1	0.16	..	..	..	..	..
Dock	1	0.08	..	..	..	..	..
Silver goldenrod	..	..	..	..	..	..	1.0
Total	80	390.00	100.0	8.9084	100.0	2.3	0.5

* In some instances, some plants in a genus could be identified to species and others could not because shoots were too young or too heavily browsed (e.g., water avens and avens). Therefore, records listed for the genus as a whole may belong to the species identified or they may include one or more other species.

§ Represents preference (in descending order).

† Figures in per cent, comparable to those for "average eaten" by deer.

‡ Value for 1959 greater than that for 1962, so 1959 figure substituted.

Comparable preferences during individual August surveys are given in Table 4. Choice was fairly consistent. Early goldenrod and woodland goldenrod were included in all four years, timothy and redtop grass in three years, and whorled loosestrife, wrinkled goldenrod, sensitive fern and hawkweed in two years. These were also preferred species during the 4-year period as a whole, except for hawkweed and redtop grass which were grazed at just below the average rate of 2.3 per cent.

In a similar manner, preferences were determined from the spring survey data recorded in 1957 and 1958 and are summarized in Table 5. Of the potential maximum production of 400 units, the recorded figure was 148 units. The average percentage eaten for all species was 1.1. Preferred species which also were rated at 1 per

Table 4. Herbaceous Food Preferences During Individual August Surveys

Species*	Average eaten (per cent)
1955	
Whorled loosestrife	2.8
Woodland goldenrod	2.6
Goldenrod	2.5
Aster	1.9
Timothy	1.6
Hawkweed	1.5
Early goldenrod	1.3
Canada bluegrass	1.2
Redtop grass	1.2
Strawberry	1.1
Total	1.1
1956	
Early goldenrod	6.9
Woodland goldenrod	6.7
Timothy	4.4
Wrinkled goldenrod	2.9
Hawkweed	2.7
Redtop grass	2.5
Total	2.3
1957	
Early goldenrod	7.4
Oxeye daisy	5.5
Whorled loosestrife	5.1
Sensitive fern	5.0
Woodland goldenrod	4.5
Timothy	4.1
Total	2.6
1958	
Bracken fern	10.0
Early goldenrod	10.0
Woodland goldenrod	5.0
Sensitive fern	5.0
White wood aster	4.7
Wrinkled goldenrod	
Redtop grass	2.8
Total	2.8

* Those species, in each year, that were eaten to a higher degree than the average and that were also rated at 1 per cent or more in availability.

TABLE 5. PREFERENCE OF DEER FOR HERBACEOUS PLANTS ON THE STUDY PLOTS DURING LATE SPRING AS INDICATED BY RELATION OF AMOUNT EATEN TO AMOUNT AVAILABLE

Species*	Use by deer (1955-1958)					
	No. of plots	Herbage available		Herbage eaten		Average eaten§ (per cent)
		Units	Per cent	Units	Per cent	
Joe pye weed	2	0.16	0.1	0.0608	3.8	38.0
Swamp saxifrage	2	0.32	0.2	0.0380	2.4	11.9
Woodland goldenrod	9	5.12	3.5	0.2150	13.6	4.2
Wrinkled goldenrod	14	8.80	5.9	0.2680	16.9	3.0
Early goldenrod	23	14.92	10.1	0.2982	18.9	2.0
Grassleaf goldenrod	29	6.22	4.2	0.0998	6.3	1.6
Bulrush	4	3.88	2.6	0.0604	3.8	1.6
Buttercup	10	1.62	1.1	0.0230	1.5	1.4
Timothy	20	6.08	4.1	0.0718	4.5	1.2
Sensitive fern	2	2.10	1.4	0.0210	1.3	1.0
White wood aster	2	0.70	0.5	0.0070	0.4	1.0
Bluegrass	1	0.20	0.1	0.0020	0.1	1.0
Sedge	15	6.78	4.6	0.0582	3.7	0.9
Canada bluegrass	14	4.38	3.0	0.0362	2.3	0.8
Sweet vernalgrass	3	3.40	2.4	0.0264	1.7	0.8
Selfheal	9	1.00	0.7	0.0078	0.5	0.8
Hawkweed	30	10.98	7.4	0.0724	4.6	0.7
Redtop grass	8	0.60	0.4	0.0040	0.3	0.7
Bedstraw	6	1.16	0.8	0.0078	0.5	0.7
Avens	4	0.36	0.2	0.0024	0.2	0.7
Oxeye daisy	15	1.22	0.8	0.0070	0.4	0.6
Speedwell	5	1.18	0.8	0.0068	0.4	0.6
Pussytoes	10	1.52	1.1	0.0080	0.5	0.5
Wild geranium	3	0.44	0.3	0.0024	0.2	0.5
Wild oatgrass	27	18.62	12.6	0.0662	4.2	0.4
Strawberry	34	7.64	5.2	0.0290	1.8	0.4
Sheep sorrel	18	2.86	1.9	0.0118	0.7	0.4
Giant goldenrod	4	0.46	0.3	0.0020	0.1	0.4
Oldfield cinquefoil	33	10.48	7.1	0.0350	2.2	0.3
Clover	7	0.60	0.4	0.0016	0.1	0.3
Agrimony	5	0.50	0.3	0.0016	0.1	0.3
Aster	21	7.14	4.9	0.0170	1.1	0.2
St. John's-wort	26	2.58	1.7	0.0062	0.4	0.2
Whorled loosestrife	14	2.22	1.5	0.0040	0.3	0.2
Water avens	4	0.90	0.6	0.0016	0.1	0.2
Hop clover	9	0.46	0.3	0.0008	0.1	0.2
Yarrow	17	2.74	1.9	..	..	..
White snakeroot	2	1.10	0.7	..	..	..
Bracken fern	1	0.80	0.5	..	..	..
Field horsetail	2	0.68	0.5	..	..	..
Panic grass	6	1.00	0.7	..	..	..
Indian Jack-in-the-pulpit	2	0.48	0.3	..	..	..
Buckhorn plantain	3	0.48	0.3	..	..	..
Elecampane	4	0.38	0.3	..	..	..
Liveforever	3	0.30	0.2	..	..	..
Pearly everlasting	2	0.24	0.2	..	..	..
Virgin's bower	2	0.50	0.3	..	..	..
Fleabane	4	0.22	0.1	..	..	..
Blueflag iris	2	0.20	0.1	..	..	..
Common plantain	1	0.20	0.1	..	..	..
Common wintercress	1	0.18	0.1	..	..	..
Common St. John's-wort	2	0.16	0.1	..	..	..

TABLE 5. (*continued*)

Species*	Use by deer (1955-1958)					
	No. of plots	Herbage available		Herbage eaten		Average eaten§ (per cent)
		Units	Per cent	Units	Per cent	
Spotted jewelweed	2	0.16	0.1	..	..	..
Wood sorrel	3	0.14	0.1	..	..	..
Thistle	2	0.08	0.1	..	..	..
Red clover	2	0.08	0.1	..	..	..
Wild carrot	2	0.06	..	..	..	..
Vetch	1	0.04	..	..	..	..
Dandelion	2	0.06	..	..	..	..
White wood sorrel	1	0.02	..	..	..	..
Butter-and-eggs	1	0.08	0.1	..	..	..
Small purple fringed orchid	1	0.02	..	..	..	..
Total	40	148.00	100.0	1.5812	100.0	1.1

* In some instances, some plants in a genus could be identified to species and others could not because shoots were too young or too heavily browsed (e.g., water avens and avens). Therefore, records listed for the genus as a whole may belong to the species identified or they may include one or more other species.

§ Represents preference (in descending order).

cent or more in availability were woodland goldenrod, wrinkled goldenrod, early goldenrod, grassleaf goldenrod, bulrush, buttercup and timothy. Non-preferred species having similar availability were sensitive fern, sedge, Canada bluegrass, sweet vernalgrass, hawkweed, pussytoes, wild oatgrass, strawberry, sheep sorrel, oldfield cinquefoil, aster, St. John's-wort, whorled loosestrife and yarrow. The major changes in preference involved bulrush and grassleaf goldenrod which were preferred in spring but not in summer and whorled loosestrife which was preferred in summer but not in spring.

Although the amount of herbage available increased from spring to summer in both 1957 and 1958 (Table 2), there was no outstanding change in percentage representation for the major species eaten by deer (Figure 2). A few species, rated as preferred or non-preferred in one season, constituted less than 1 per cent of the total supply available during the other season. Among the important spring foods, such species were buttercup and sweet vernalgrass; among summer foods they were bracken fern, redtop grass, selfheal, hop clover and white snakeroot.

Use of herbage by animals other than deer was generally greater in 1962 than in 1959, although for two species, whorled loosestrife and strawberry, it was greater in 1959. The figures, representing the higher degree of use in each case, are given in Table 3. For most

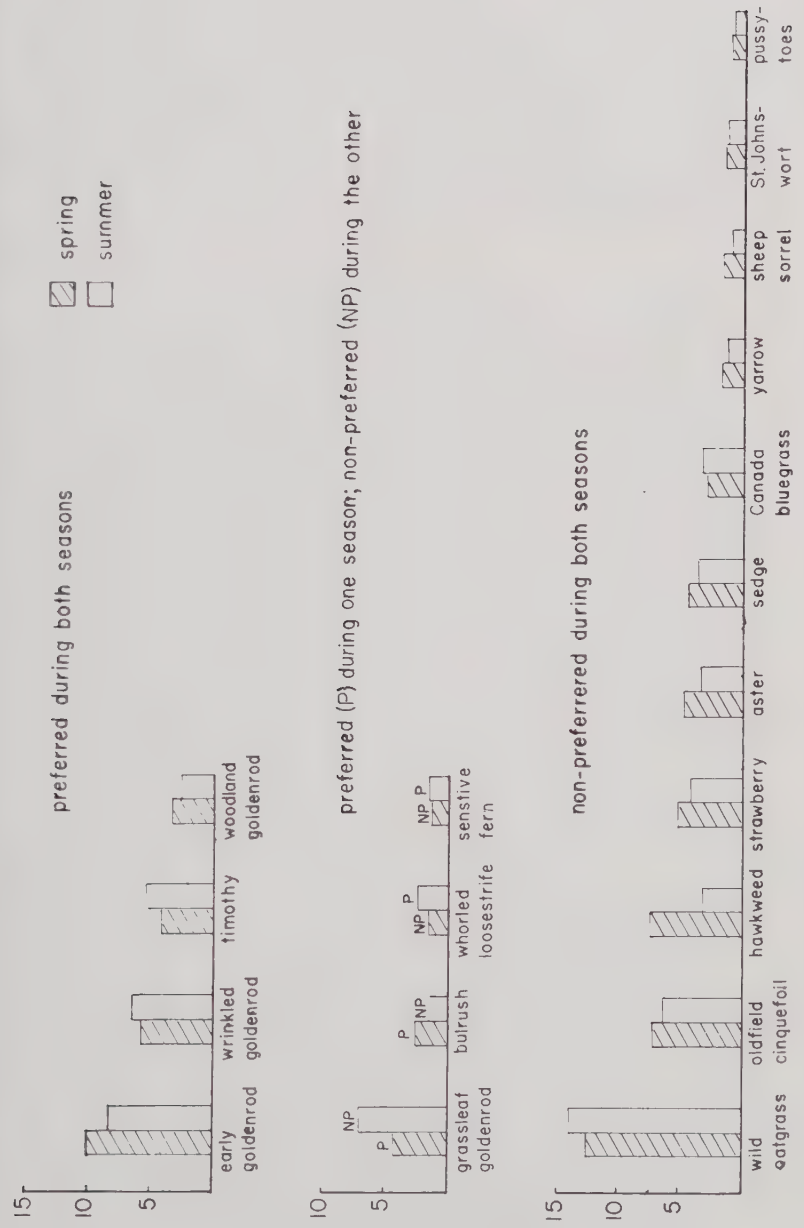

Figure 2. Relative availability in spring and summer for major herbaceous species eaten by deer.

plants, consumption was markedly less than that by deer. Animals observed in 1962 included woodchuck (*Marmota monax*), cottontail rabbit (*Sylvilagus floridanus*) and porcupine (*Erethizon dorsatum*), and signs of varying hare (*Lepus americanus*) and raccoon (*Procyon lotor*) were noted. Other small mammals and various birds would also feed on herbaceous vegetation. Since little is known about the interaction of small mammal and bird populations with deer, these figures are not presumed to represent the use by other species during the years when deer were present on the area.

DISCUSSION

Food in the enclosure was adequate to allow deer a choice. The average percentage eaten for all herbaceous species recorded was only 2.3 for the 4-year period. What part of the deer's total diet was comprised of herbaceous species is unknown, but it was undoubtedly minimal. Watts (1964) found that three tame deer spent 94 per cent of their summer feeding time eating green leaves, mainly of woody species. Webb (1959) found that, in approximately two deer-days of use in an Adirondack area previously exclosed to deer, woody species had been browsed but there was no indication of feeding on herbaceous plants. Palmer (1951), reporting observations in Maine, stated "The deer show no particular liking for the plentiful supply of grass that grows on the camp grounds."

In contrast, Dunkeson (1955) found that in the Missouri Ozarks the summer diet of one deer which could be closely observed consisted mainly of green broadleaved herbaceous plants. Asters and goldenrods were preferred, although mushrooms, fruits and seeds were seasonally important. He also noted that a large part of deer browsing could not be detected by examining plants because of the nature of the deer's diet and eating habits and because new growth obliterated some signs of browsing.

One of the major variables in the study reported here was the differing number of days fawns were present on the area previous to each August survey as indicated in Table 2. It is generally conceded that fawns are weaned when about 4 months old (Taylor, 1956). However, literature on use of herbaceous vegetation by fawns is scant. Palmer (1951) wrote "Broad-leaved plantains, *Plantago major*, are much sought on the camp grounds and are eaten very selectively. I observed that a buck fawn, Flag, at the age of about 50 days, ate these plantains with seeming relish, also dandelions (*Taraxacum officinale*) ... According to Mr. Cram, fawns from about their fourth day on eat a small amount of grass and other ground herbage." Nichol (1938) wrote "Although the young nurse heavily

for sixty days, they will begin to forage on grass tips and browse when two or three weeks old."

Fawns have been observed eating on several occasions by J. E. Tanck of the New York State Conservation Department. On June 10, 1954, one was observed feeding on Canada bluegrass, aster, hawkweed and strawberry. On June 14, 1954, one was observed feeding on hawkweed, oldfield cinquefoil, aster, fleabane, red clover and goldenrod. On August 14, 1958, one was observed feeding on knotweed, tall yellow wood sorrel, catnip, buckhorn plantain, butter-and-eggs, Canada bluegrass, lilac, cinquefoil and clover.

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CHEMICAL PROPERTIES, PHYSICAL PROPERTIES AND PLANT GROWTH IN TWENTY ARTIFICIAL WILDLIFE MARSHES[1]

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ABSTRACT

Measurements of physical and chemical characteristics of water and bottom soil were made throughout each season from 1960 to 1967 on 20 artificial marshes to determine factors that influenced the growth of aquatic plants important as food sources for wildlife. Water depth was varied from 1 to 3 feet, and throughout the study greater plant growth was observed in the shallower marshes. Additions of organic matter to the bottom soils resulted in increased plant growth early in the study, but in later years they had little effect. The additions of limestone to this neutral to calcareous soil material had no effect on plant growth. Of the factors measured, extractable iron in the sediment increased at an increasing rate while extractable manganese increased only slightly over the course of the study. Total alkalinity of the water decreased consistently throughout the first six years, but it increased during the last two years of the study. At the conclusion of this stage of the investigation, factors controlling productivity in these marshes were not known with any certainty.

Wildlife marsh development is a unique on-the-land management for the conservation of a variety of natural resources. Of the benefits that may accrue from such a program, the increase in waterfowl habitat is of special concern. Wetland quality, assuming favorable water depths, is dependent on the properties of the flooded soils which are determined by the properties of the sediments of the marsh itself as well as those brought into the marsh by runoff water, rainfall, eroded materials, etc.

Effective, economical marsh management practices are not known with any degree of certainty. Most of the practices are based on experience rather than sound scientific principles. It has been observed in many marshes in New York that productivity immediately after flooding is very high. After this vigorous flush of growth, productivity begins to decline and, in many marshes after a few years, production of wildlife food is reduced drastically. By trial and error it has been found that draining the marshes and aerating the soils leads to enhanced growth when they are subsequently reflooded.

Cook and Powers (1958) studied several nonproductive marshes in the early and mid-1950's. By analyzing the bottom soils they dis-

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covered that the extractable iron, as determined by the methods of Greweling and Peech (1965), built up to extremely high levels in the sediment. While the oxidation state of the iron was not determined in these samples it was believed, since the areas had been submerged for a number of years, that most of it was in the Fe^{2+} form. Ferrous iron is more soluble generally than ferric forms of iron. Manganese was fairly high in many of these soils also. Presumably it was also present in the reduced form as Mn^{2+}. It was believed on the basis of the data accumulated by Cook and Powers (1958) that Fe^{2+} and possibly Mn^{2+} were present in the sediments in sufficiently high quantities to be toxic to plant growth in the marshes they studied. Rather than to present a comprehensive literature review the reader is referred to the report by Harter (1966) who discussed the chemistry of anaerobic soils and to the important studies by Ponnamperuma (1967) and Ponnamperuma *et al.* (1967) on aqueous carbonate and redox equilibra in flooded soils.

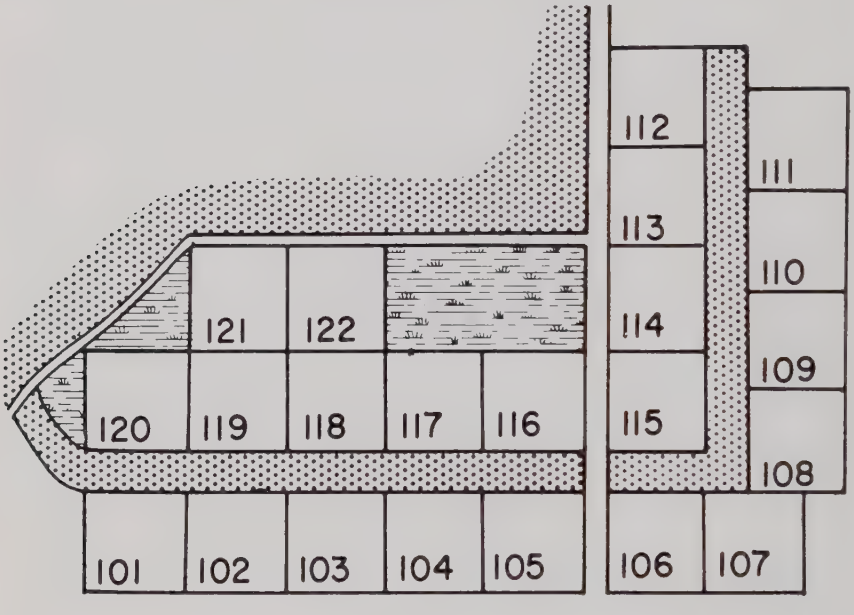
To study in detail both the chemitsry of the soil and the chemistry of the water and their influence on introduced plant species, 20 one-tenth-acre marshes were constructed in 1958 and 1959. Collection of data began in 1960. This report is a summary of much of the data that were collected from these marshes from 1960 to 1967. Thus, it is a progress report and a statement of some aspects of the work that might be continued further.

PROCEDURE

The 20 one-tenth-acre impoundments, along with an additional impoundment to ensure an adequate water supply, were constructed at a site near the Tompkins County Airport where an adequate supply of water was available. The marshes were 66 feet on a side and the dikes around each marsh were thrown up by removing material from the basin. Thus the floor of each marsh was well into the glacial till material underlying the area. In constructing the dikes, stones were removed. The materials occurring at the site contained about 16 per cent clay, 50 per cent silt and 34 per cent sand. In order to prevent leakage, the marshes were lined with a soil material containing 44 per cent clay and only 5 per cent sand to a depth of about 6 inches and thoroughly compacted.

The experiment was planned to evaluate the influence of water depth, soil reaction and organic matter on the growth of rooted aquatics. Water depths were maintained, at intervals of 6 inches, from 1 foot to 3 feet in different marshes for a total of five depths. Soil reaction was to be either high or low, and likewise organic matter was to be either high or low. Thus, with all combinations in-

cluded, the experiment consisted of a factorial of five water depths x two soil reactions x two organic matter levels for a total of 20 impoundments. The layout of the experimental area including the treatments imposed is shown in Figure 1.



No.	Water depth (feet)	Treatment	
		Lime	Organic matter
101	2.5	Low	Low
102	3.0	Low	High
103	1.5	Low	Low
104	2.5	High	High
105	3.0	High	Low
106	1.0	Low	High
107	2.5	Low	High
108	1.0	High	Low
109	2.0	Low	High
110	2.0	High	High
111	2.0	Low	Low
112	1.0	High	High
113	2.5	High	Low
114	1.5	High	High
115	1.5	Low	High
116	1.5	High	Low
117	3.0	High	High
118	1.0	Low	Low
119	3.0	Low	Low
120	2.0	High	Low

Figure 1. Diagram of marsh layout and index to lime and organic matter treatments. (Nos. 121 and 122 constituted a water-supply impoundment.)

To those units to be maintained at a high soil reaction, ground limestone was added at the rate of 10 tons per acre (1 ton per marsh) and mixed with the soil. The object was to assure a soil pH of at least 7.5. Organic matter in the form of a productive organic soil was added at the rate of 40 tons per acre dry matter (4 tons per marsh) to those units which were to be high in organic matter. The organic matter was added to the surface of the soil and was equivalent to about 12 per cent organic matter considering only the upper 2 inches of soil. To preclude a lack of nutrients, mineral fertilizer (5-10-5) was added to each marsh before flooding at the rate of 300 pounds per acre (30 pounds per marsh).

Aquatic vegetation was planted in each marsh in order to determine the influence of the treatments on vegetative productivity. The plants selected for study were: burreed (*Sparganium americanum*), wild rice (*Zizania aquatica*), water smartweed (*Polygonum amphibium*) and hardstem bulrush (*Scirpus acutus*) as emergents; water naiad (*Najas flexilis*), chara (*Chara* sp.), sago pondweed (*Potomageton pectinatus*) and water celery (*Vallisneria americana*) as submergents. Each of the eight species appeared in each marsh four times in randomly distributed 4 x 10-foot subplots. It was the intent that each species be maintained in the subplots so that a rather precise record of vegetative production could be kept over the course of the experiment. It was soon evident, however, that it was not possible to maintain the subplots, but harvests of plant material were taken at intervals and visual ratings of growth of the introduced species were made annually so that these data could be correlated with various other measurements made on the soil and water in the marshes.

The water in the marshes was analyzed weekly during the growing season at several depths, including the surface and the water-mud interface, for total alkalinity and dissolved oxygen by the methods described by Ellis *et al.* (1948) and for pH with a Beckman pH meter. Water temperature was measured with an immersion thermometer at the time the samples were taken.

Soil samples were taken quarterly in April, July, October and January for analysis. A core was taken from each marsh by driving a corer containing a plastic sleeve into the soil to a depth of about 8 inches. When the core was removed from the soil, the plastic sleeve was removed from the corer, stoppered at both ends, and placed in a deep freeze until ready for analysis. Only that portion of the core that appeared to be influenced by plant growth was used for analysis. The extractable elements, i.e., phosphorus, potassium, calcium, magnesium, ammonium nitrogen, nitrate nitrogen, iron, aluminum and manganese, were determined for each sample according

to the methods of Greweling and Peech (1965) and are reported in this paper on a wet soil basis. In addition, pH and organic matter content were determined for all samples according to the methods of Greweling and Peech (1965).

Since "within-season" fluctuations and trends were not great, most of the data were combined to provide seasonal averages. Seasonal averages were calculated from the weekly analyses of water samples taken from June to September. Twelve to 14 individual values were included in these averages and are so reported in the tables. Soil samples were taken quarterly so that four values were averaged to provide the information included in the tables. In addition, some calculations were made to determine the relationship between measurements and ratings of plant growth and various chemical and physical factors measured.

RESULTS AND DISCUSSION

The information recorded concerning water and soil characteristics and plant growth are presented separately.

Water Analysis

Throughout the study, the water in the marshes was analyzed for variations in pH, alkalinity and oxygen content, particularly in relation to the treatments applied.

Water pH Water pH measured during the growing season throughout the study varied from about 8 to values of 10 or slightly above. There was little variation in these values from one part of the season to another or from season to season. In addition, diurnal variation was slight, i.e., from about 8 to 10 in almost all instances. The pH tended to increase during the day as the carbon dioxide tended to be depleted, as would be expected. This might well indicate that the pH of the water was controlled by the carbonate-bicarbonate system in these waters.

Water Alkalinity The mean total alkalinity of the water in the marshes, according to water depth and organic matter additions, is given in Table 1. There was a trend for total alkalinity to decline from 1960 through 1965, but it was markedly higher in 1966 and 1967. There also was a trend for the total alkalinity to be higher in the shallower marshes and to be slightly higher in those which received organic matter additions. There was some seasonal fluctuation, with values tending to be somewhat higher in late fall and winter than during the growing season. The depth at which a sample was taken had no effect on the total alkalinity measured. Therefore, all the results summarized in Table 1 represent analyses made on samples taken at the surface of the water.

TABLE 1. YEARLY MEANS OF TOTAL ALKALINITY ACCORDING TO WATER DEPTH AND ORGANIC MATTER TREATMENT FOR WATER SAMPLES FROM THE EXPERIMENTAL MARSHES

Water depth (feet)	Organic matter treatment	Total alkalinity*							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	156	74	71	60	71	41	101	121
	Low	101	76	50	43	57	35	93	104
1.5	High	151	76	54	49	69	41	102	112
	Low	121	104	62	46	55	31	81	92
2.0	High	123	66	51	48	56	31	75	80
	Low	117	86	64	47	56	31	71	76
2.5	High	120	76	56	50	52	30	70	66
	Low	108	84	61	42	47	27	56	64
3.0	High	113	73	55	48	52	31	59	63
	Low	107	86	65	52	48	25	61	60
Mean	High	133	73	57	51	60	35	82	88
	Low	110	87	60	46	52	30	72	79
Over-all mean		122	80	59	48	56	33	77	84

*In ppm of calcium carbonate ($CaCO_3$).

In Table 2 are given the number of determinations falling in the various ranges of total alkalinity for the years 1962 through 1967. These data again point out the decline in total alkalinity through 1965 and the general increase in 1966 and 1967. Many of the high values measured in 1966 and 1967 were found in the late fall and winter.

The carbonate system, along with providing the necessary carbon for plant growth, provides buffering and neutralizing effects in the water system. The carbonate system serves as a mechanism for the precipitation of heavy metals such as iron, manganese, zinc or copper and other materials that may enter the water. Thus, as total alkalinity declines, the potential for building up toxic levels of various elements or other materials in the system increases. Indeed, one of the possibilities for decline in productivity in wildlife marshes is the increase to toxic levels of iron and manganese in the water or the bottom material. It appeared, through 1965, that total alkalinity might fall low enough to permit toxic levels of the heavy metals to accumulate. The increase in values in 1966 and 1967 may well have precluded this possibility at that time. The reason for the increase during the last two years is not obvious from any of the data available, although the seasons from 1962 through 1965 were extremely

TABLE 2. NUMBER OF DETERMINATIONS ACCORDING TO RANGE OF TOTAL ALKALINITY

Range*	Number of determinations					
	1962	1963	1964	1965	1966	1967
100+	6	0	21	0	183	303
90-99	29	3	7	1	58	94
80-89	91	11	31	0	84	103
70-79	79	39	83	2	134	143
60-69	253	109	185	23	178	200
50-59	530	281	671	57	340	198
40-49	262	727	498	176	228	61
30-39	11	108	4	472	2	1
20-29	1	1	0	635	0	0
<20	0	0	0	29	0	0
Total	1,262	1,279	1,500	1,395	1,207	1,103

*In ppm of calcium carbonate ($CaCO_3$).

dry during the sampling season. Beginning in 1966 and continuing through 1967, significantly more rainfall occurred during the growing season. These differences as well as other factors that might have been associated with these changes in yearly weather pattern may account for the variations in total water alkalinity measured.

OXYGEN CONTENT The oxygen content of the water was measured routinely also. Values ranged from about 1 ppm to over 15 ppm dissolved oxygen depending on the time of the year and on conditions. Substantial diurnal fluctuation in dissolved oxygen concentration in the water was observed during the growing season (Table 3). Oxygen values fell to low levels only in early morning hours when photosynthetic activity was reduced compared with other biological activity. Photosynthetic activity during the daylight hours re-established the oxygen in the water to near saturation levels. As with total alkalinity, there was little variation in oxygen concentration with water depth. Oxygen concentration fell to lower values in the shallower marshes during the growing season, probably due to higher biological activity and biological oxygen demand in these marshes.

At no time in any of these marshes did the dissolved oxygen in the water fall to zero. Thus, even during periods of greatest biological activity, the marshes remained aerobic throughout. None of the imposed factors except water depth had any effect on the content of dissolved oxygen. Since biological activity was generally higher in the shallower marshes, the oxygen content of the water seems to have been more closely related to biological activity than to water depth *per se*.

TABLE 3. TYPICAL VARIATIONS IN WATER TEMPERATURE AND DISSOLVED OXYGEN DURING A DAY.

Time	Temperature in degrees Centigrade	Oxygen content in ppm
5:00 p.m.	22.5	7.55
6:00	23.5	8.87
7:00	24.0	9.49
8:00	23.5	8.47
9:00	23.5	8.06
10:00	23.0	7.75
11:00	23.0	7.45
12:00	23.0	6.94
1:00 a.m.	22.5	6.53
2:00	22.0	5.20
3:00	22.0	4.49
4:00	21.5	3.98
5:00	21.0	3.06
6:00	21.0	2.14
7:00	21.0	2.04
8:00	21.0	2.75
9:00	22.0	5.41
10:00	23.0	6.12
11:00	23.0	8.26
12:00	23.0	7.96
1:00 p.m.	23.5	8.67
2:00	24.0	9.79
3:00	24.5	10.10
4:00	25.5	11.52
5:00	26.0	11.42

SOIL ANALYSIS

The soils of the marshes were analyzed with respect to pH, organic matter content and the presence of certain minerals and their relationship to the treatments applied.

SOIL PH As shown in Table 4, soil pH varied but little from year to year or as a consequence of treatment. The soil of the area where the ponds were constructed is Langford silt loam. This soil is acid in the surface horizons, but the pH rises with increasing depth and the underlying glacial till is neutral to mildly calcareous. Since, in the construction of the marshes, soil material was excavated down to or near the glacial till material, the actual pH values measured were those of the underlying till rather than the more acid upper horizons. This belief is borne out by the fact that the pH values were near those expected in a calcareous material. This view is further supported by the fact that the additions of limestone had no influence on the pH values measured in these bottom samples.

TABLE 4. INFLUENCE OF LIMESTONE ADDITIONS ON THE SOIL OF THE MARSH BOTTOM

Water depth (feet)	Limestone addition	Soil pH							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	7.9	8.0	8.0	7.7	8.0	7.7	7.8	7.7
	None	8.0	8.1	8.1	7.8	8.0	7.7	7.9	7.8
1.5	High	8.0	7.9	8.0	7.7	7.7	7.7	7.9	7.9
	None	7.8	8.0	8.0	7.8	8.0	7.7	7.8	7.7
2.0	High	7.8	8.0	7.9	7.7	7.9	7.8	7.9	7.8
	None	7.9	8.1	8.0	7.7	8.0	7.7	7.7	7.6
2.5	High	8.0	8.0	8.0	7.7	8.0	7.7	7.7	7.8
	None	7.9	8.0	8.0	7.7	8.0	7.6	7.7	7.7
3.0	High	8.0	8.0	8.0	7.8	8.0	7.8	7.9	7.7
	None	7.9	8.1	8.1	7.8	8.0	7.7	7.8	7.7
Mean	High	7.9	8.0	8.0	7.7	7.9	7.8	7.8	7.8
	None	7.9	8.1	8.0	7.8	8.0	7.7	7.8	7.7
Over-all mean		7.9	8.0	8.0	7.8	8.0	7.8	7.8	7.8

Since these marshes are essentially closed systems with a minimum of water movement through them, it is highly improbable that the calcium carbonate ($CaCO_3$) will be leached from these materials. Therefore there is little likelihood that any change in the soil pH, or for that matter in the water pH, as a consequence of soil changes will be found in the foreseeable future.

ORGANIC MATTER CONTENT The organic matter content of the samples of marsh bottom soil are given in Table 5. The organic matter content of the soils receiving no organic matter additions (low) were fairly typical of values found for subsoils in this area. They were also reasonably uniform, as might be expected for these soil materials. On the other hand, the values for the high treatment, while very erratic, were consistently much higher than those for the low treatment. The material was added to the surface and mixed only slightly. Two reasons probably account for the variation in these values. Only one core was taken from each marsh at each sampling. Four samples were taken from each marsh annually. Since half the marshes received organic matter and half did not, data obtained were combined for the two marshes having the same organic matter treatment at each water depth. Thus, the values in Table 5 are the average of eight determinations. In the laboratory, only that part of the core influenced by biological activity was used for analysis. The

TABLE 5. INFLUENCE OF ORGANIC MATTER TREATMENT ON THE ORGANIC MATTER CONTENT OF THE MARSH BOTTOM SOILS

Water depth (feet)	Organic matter treatment	Organic matter content (per cent)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	15.39	3.32	1.10	1.17	1.23	3.85	2.89	1.76
	Low	0.68	1.70	0.60	0.83	0.41	0.59	0.54	1.00
1.5	High	4.05	6.50	6.48	1.26	0.80	3.25	2.50	3.89
	Low	0.90	0.64	0.65	0.94	0.48	0.64	0.77	1.02
2.0	High	27.85	6.03	2.01	1.02	1.10	2.26	4.33	4.56
	Low	0.64	0.68	0.74	0.96	0.47	0.57	0.75	0.86
2.5	High	2.35	8.48	2.29	3.32	1.14	1.13	2.20	3.61
	Low	0.66	0.69	0.61	0.77	0.39	0.72	0.64	0.78
3.0	High	7.78	9.18	1.87	1.40	0.79	0.85	1.54	4.00
	Low	0.66	0.79	0.58	0.73	0.53	0.59	0.79	1.22
Mean	High	11.48	6.70	2.75	1.63	1.07	2.27	2.50	3.56
	Low	0.72	0.90	0.64	0.84	0.45	0.62	0.69	0.98

sampling problems both in the field and in the laboratory then may account for the variation, especially in the first two or three years.

Concerning the data two very interesting trends are apparent. First, the organic matter content in the high-treatment marshes appeared to decline at quite a rapid rate from 1960 to 1965. In the years 1966 and 1967, this trend was reversed and organic matter apparently increased in these marshes. In the low-treatment marshes little change was observed until about 1965 when their organic matter content began to increase. The decline in the organic matter content of the high-treatment marshes could have been more apparent than real due to initial mixing and subsequent sampling along with other factors. It does seem, however, that there was a real decline in the organic matter content due to decomposition of the added organic material. In fact, if the amount of decline was real, the rate of decomposition of the organic matter was more rapid than might normally be anticipated. In the last two years, however, the soil organic matter content in both sets of marshes apparently was increasing. This trend is likely to continue in the future, and the rate of accumulation likely will be related to the variations in plant growth in the different marshes.

BASE CONTENT The content of the bases, i.e., calcium, magnesium and potassium, in the sediment was not related to any obvious characteristic of the marshes. The extractable calcium present in the samples was very high, ranging from approximately 10,000 ppm to values approaching 30,000 ppm depending on the sample. This range

of variation was found in different samples from marsh to marsh. Since the extracting solution used will dissolve calcium carbonate ($CaCO_3$), the values found may well reflect variations in the amount of limestone in the individual sample taken. No difference in calcium level was found between the samples from the limed marshes and those from the unlimed marshes, again indicating that the calcereous nature of the till upon which these marshes were constructed was dominating the calcium content.

Likewise, the magnesium content of the samples was high and ranged from over 500 ppm to over 1,500 ppm in individual samples. Since most of the limestone materials present in this area contain some magnesium and since there are magnesium-bearing minerals present in the soils, it was not surprising to find the levels high. The wide range of values found was undoubtedly due to the wide range in limestone content of the till material samples.

The extractable potassium content of the samples was moderately low and quite constant from marsh to marsh and from year to year. The potassium level ranged from 20 to 35 ppm in all the samples regardless of prior treatment or the year of sampling. There was no obvious trend in these values throughout the experiment.

ALUMINUM CONTENT The level of extractable aluminum in the soils was low and not affected by additions of limestone (Table 6). Annual changes in the aluminum level in the soils was insignificant.

TABLE 6. YEARLY MEANS OF EXTRACTABLE ALUMINUM IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND LIMESTONE TREATMENT

Water depth (feet)	Limestone treatment	Aluminum (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	13	62	14	16	12	23	16	26
	None	14	13	17	12	12	16	17	28
1.5	High	21	15	20	18	30	20	24	24
	None	12	16	14	17	18	19	23	27
2.0	High	8	15	12	14	26	21	13	25
	None	12	12	21	16	18	27	23	29
2.5	High	14	11	13	11	15	35	21	28
	None	16	18	14	10	15	23	19	30
3.0	High	20	13	16	11	26	33	17	35
	None	11	11	13	15	24	20	24	23
Mean	High	15	23	15	14	22	26	18	28
	None	13	14	16	14	17	21	21	27
Over-all mean		14	19	16	14	20	24	20	28

Since soil pH is the single controlling factor in the amount of extractable aluminum in soils, it is not surprising that the values were low and that no changes of consequence occurred. The levels of extractable aluminum given in Table 6 are in the range where no influence on plant growth should be observed. Furthermore, it is reasonable to expect the aluminum levels to remain low and in the non-toxic range as long as the soil pH remains unchanged.

INORGANIC NITROGEN CONTENT The quantity of inorganic nitrogen (NO_3 plus NH_4) in the soil extracts is given in Table 7. The values in the table are the sums of the quantity of nitrogen found in the

TABLE 7. YEARLY MEANS OF INORGANIC NITROGEN IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND ORGANIC MATTER TREATMENT

Water depth (feet)	Organic matter treatment	Inorganic nitrogen (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	18	10	17	7	7	18	23	18
	Low	4	9	13	7	5	14	22	20
1.5	High	6	13	15	8	4	15	21	20
	Low	5	12	13	6	6	14	25	20
2.0	High	10	8	16	7	5	22	21	22
	Low	12	10	14	7	7	16	26	17
2.5	High	5	9	13	6	7	20	25	19
	Low	4	5	12	7	4	23	23	18
3.0	High	18	12	14	6	10	15	23	18
	Low	5	11	13	6	5	19	23	21
Mean	High	11	10	15	7	7	18	23	19
	Low	6	9	13	7	5	17	24	19
Over-all mean		8	10	14	7	6	18	24	19

extract as nitrate and ammonium ions. Actually, in almost all cases a high percentage of the nitrogen was present as the nitrate. This would indicate that at least part of the soil zone was remaining oxidized. While no evidence is available from these studies as to the extent of possible nitrate reduction in these soils, the fact that nitrate was present in all samples regardless of the season of the year they were taken indicated that oxidation was prevalent. No influence of the initial additions of organic matter on the inorganic nitrogen content was noticeable, nor was water depth influential.

IRON CONTENT The quantities of extractable iron present in the samples taken from the marsh bottom are given in Tables 8 and 9.

In Table 8, the influence of the original limestone additions on the quantities of extractable iron are given and, in Table 9, the influence of the original organic matter additions are shown. The oxidation state of the iron extracted is not known; however, it is likely that most, if not all of it, was in ferrous form. Lathwell and Peech (1964)

TABLE 8. YEARLY MEANS OF EXTRACTABLE IRON IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND LIMESTONE TREATMENT

Water depth (feet)	Limestone treatment	Iron (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	48	109	65	95	49	160	269	236
	None	23	51	52	48	53	70	220	338
1.5	High	29	38	91	62	230	125	266	239
	None	148	97	64	86	81	74	259	291
2.0	High	29	40	57	67	90	140	109	242
	None	32	41	101	95	113	182	391	312
2.5	High	20	29	37	42	45	205	220	244
	None	28	39	40	33	49	109	243	176
3.0	High	67	75	75	41	220	217	142	474
	None	31	31	39	60	60	78	221	279
Mean	High	38	58	65	61	127	169	201	287
	None	52	52	59	64	71	103	267	279
Over-all mean		45	55	63	63	99	137	234	283

have shown that the amount of iron extracted from arable soils increases rapidly as the soil pH falls below 5.5. In these marsh-bottom soils with their initial high pH, little influence of the additions of lime was evident on the extractable iron levels.

The other major influence on the quantity of extractable iron in the soil is the oxidation state of the soil. In an aerated soil, iron is found in the ferric state usually as highly insoluble oxides. As the soil becomes reduced, the iron is reduced to the ferrous state, and in general this form is more soluble than the ferric forms. In addition, reduction of iron would be expected to proceed more rapidly in the presence of added organic matter because of biological reduction due to increased biological activity. Therefore, higher levels of extractable iron might be found in those marshes where organic matter was added. As shown in Table 9, there was some trend for the extractable iron to be higher in the soils which received the additions

TABLE 9. YEARLY MEANS OF EXTRACTABLE IRON IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND ORGANIC TREATMENT

Water depth (feet)	Organic matter treatment	Iron (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	50	37	75	88	59	198	288	213
	Low	22	123	42	55	43	82	202	361
1.5	High	149	109	110	107	89	114	299	260
	Low	29	26	45	41	222	85	226	270
2.0	High	29	50	71	78	102	207	345	408
	Low	22	31	87	84	100	114	273	229
2.5	High	22	36	50	24	52	121	331	222
	Low	25	32	26	52	42	193	132	198
3.0	High	30	38	58	59	245	135	161	268
	Low	68	68	56	42	35	160	201	984
Mean	High	56	54	73	71	109	145	278	274
	Low	35	56	51	55	88	127	207	308
Over-all mean		45	55	63	63	99	137	242	291

of organic matter. This trend is best shown in Figure 2. The differences may or may not have been significant because of the high variability from sample to sample.

In earlier work Cook and Powers (1958) showed that, in marshes developed on acid materials, extractable iron (presumably Fe^{2+}) reached very high and undoubtedly toxic levels very rapidly. In the marshes they studied, iron levels reached values of greater than 1,500 ppm on a wet soil basis, and plant growth was severely limited. In the present marshes there was only a gradual increase in the extractable iron levels during the first four years, while during the last four years the extractable iron increased at an increasing rate. This is illustrated in Figure 2. Whether this trend will continue must await further data. Although it is doubtful that levels in 1967 were sufficiently high to adversely affect plant growth, if they continued, toxic levels of iron would probably have been reached soon.

On the other hand, the iron levels measured in these soils should be viewed with caution. Lathwell and Peech (1964) have shown that poorly drained calcareous subsoils contain appreciable amounts of extractable iron. Under these conditions, ferric iron (Fe^{3+}) was reduced and possibly accumulated as the mineral siderite ($FeCO_3$). Siderite, however, is soluble in the Morgan's extracting solution used on these samples, and the high amounts of iron extracted indicated

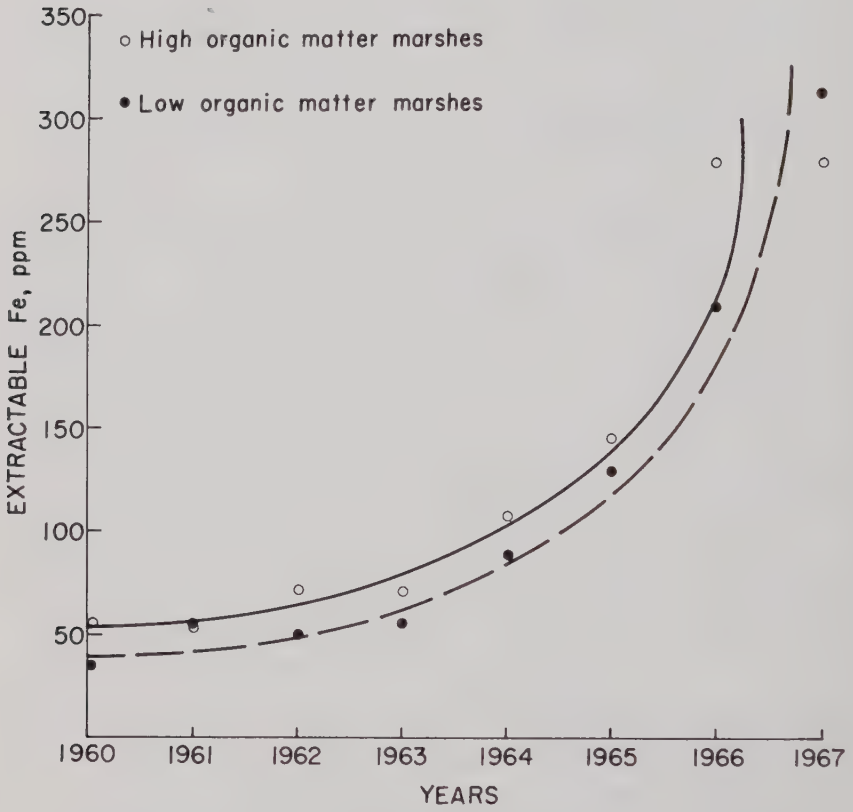


Figure 2. Trend in the level of extractable iron in the marsh soils during the study in relation to addition of organic matter.

reducing conditions. Since ferrous carbonate among others (Ponnamperuma, 1967) accumulates under poorly aerated calcareous conditions, it is possible that the concentration of ferrous iron (Fe^{2+}) in solution was being controlled by the sparingly soluble ferrous carbonate formed under the conditions found in these marshes. Thus, in contrast to the situation observed by Cook and Powers (1958), the productivity of these marshes may have been unaffected by high concentrations of soluble ferrous iron (Fe^{2+}) because of its precipitation as a ferrous carbonate.

Another possibility that cannot be precluded is that there is an oxidized soil zone which occurs at the water-soil interface that may be no more than a few millimeters in thickness. In this zone, ferric iron would be precipitated although the core sample actually analyzed was dominated by the underlying reduced material. If ferrous iron (Fe^{2+}) diffused from the soil toward the water phase, it might be

oxidized in the zone at the interface and thus be precipitated. Since aquatic plants root mainly in the first few millimeters of soil or obtain their nutrients from the water directly, an oxidized zone may function to preclude levels of ferrous iron high enough to be detrimental to plant growth. Another factor that indicates the samples extracted might well have been a composite of a reduced zone and an oxidized zone was the presence of significant quantities of nitrate nitrogen in the extract. It is highly unlikely, indeed, that any nitrate would have been produced in the reduced portion of the soil zone. The presence of extractable iron, however, in samples at the pH values found could only have been the result of reduced conditions.

Precipitation of ferrous iron as siderite ($FeCO_3$) or the precipitation of iron in the ferric form (Fe^{3+}) in an oxidized zone are both possibilities that could have occured in these soils. Since plant growth was not severely affected in these marshes, it is reasonable to postulate that either or both of these mechanisms may have been operative. With further investigation it may be possible to clarify the actual conditions that exist.

Still another possibility is that sulfide forms under extreme reducing conditions. Sulfide in any quantity can have serious consequences on vegetation. Sulfide probably reacts with both ferrous iron and ferric iron (Harmsen, 1964) although the end product under strong reducing conditions is ferrous sulfide. In this case the precipitation of the ferrous iron as the sulfide might reduce the concentration of both ions to levels suitable for normal plant growth. The precipitation of ferrous sulfide seems less likely than the other possibilities to have determined the productivity of these marshes. But at this point evidence is not available to eliminate entirely this possibility.

Manganese Content The extractable manganese content of the marshes is given in Tables 10 and 11. As shown in Table 10 the original limestone treatments had little effect on the extractable manganese present. Likewise, the original additions of organic matter showed little influence on the extractable manganese (Table 11). From 1960 through 1966, there was a gradual trend upward in the quantity of extractable manganese recorded, but in 1967 this trend was reversed. Whether this reversal was significant is obviously unknown at this time.

As noted by Lathwell and Peech (1964) considerable caution must be exercised in interpreting data for manganese. They pointed out that considerable manganese (as Mn^{2+}) extracted by the Morgan's extracting solution may be derived from this form of manganese

TABLE 10. YEARLY MEANS OF EXTRACTABLE MANGANESE IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND LIMESTONE TREATMENT

Water depth (feet)	Limestone treatment	Manganese (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	130	145	153	154	140	126	179	129
	None	102	132	141	137	138	138	169	127
1.5	High	138	132	168	162	169	147	174	118
	None	99	142	119	130	138	116	155	122
2.0	High	114	126	134	141	139	147	163	118
	None	123	131	161	148	160	165	175	124
2.5	High	87	121	142	146	132	139	151	128
	None	127	132	144	130	122	157	169	127
3.0	High	132	142	165	144	178	172	157	152
	None	121	122	134	134	138	137	170	103
Mean	High	120	133	152	149	152	146	165	129
	None	114	132	140	136	139	143	168	121
Over-all mean		117	133	146	143	146	145	167	125

TABLE 11. YEARLY MEANS OF EXTRACTABLE MANGANESE IN THE MARSH BOTTOM SOILS ACCORDING TO WATER DEPTH AND ORGANIC MATTER TREATMENT

Water depth (feet)	Organic matter treatment	Manganese (ppm)							
		1960	1961	1962	1963	1964	1965	1966	1967
1.0	High	130	137	155	163	143	124	158	134
	Low	102	140	140	128	135	139	189	122
1.5	High	110	150	149	156	147	129	160	104
	Low	127	124	137	135	160	134	169	135
2.0	High	113	131	148	128	151	159	169	111
	Low	124	126	142	161	148	153	172	128
2.5	High	104	133	164	124	141	135	163	115
	Low	110	120	122	152	113	161	157	140
3.0	High	126	127	154	147	172	160	161	107
	Low	127	137	145	131	144	149	166	148
Mean	High	116	135	154	144	151	141	161	144
	Low	118	129	138	141	140	147	170	135
Over-all mean		117	132	146	143	146	144	166	125

chelated by organic matter. This chelated manganese is insoluble and therefore unavailable to plants, so that measurement of the extractable manganese by the methods used on these soils may have overestimated the quantity of manganese available to plants in these marshes.

It is conceivable that manganese (as Mn^{2+}) is the factor most detrimental to the growth of plants. Iron in the system should become reduced before any appreciable fraction of the manganese is reduced. In fact, as Harter (1966) pointed out, ferrous iron might well participate in the reduction of manganese oxide (MnO_2) to produce manganese (Mn^{2+}) and ferric iron (Fe^{3+}). In this case, iron might be eliminated as a factor while manganese could become more involved in influencing plant growth.

Plant Growth

In the early stages of the experiment, invader plants were removed and it was possible to estimate the influence of various factors on the growth of the introduced plants.

Measurements and Ratings In 1960 and 1961 harvests of wild rice were made since it was well distributed throughout the marshes. Because the growth habit of this plant is such that it could be used to represent a complete growing season, it was used to represent the growth potential of each unit. After that, the species growing in the marshes were tabulated, and the relative proportions of the introduced species as well as the invading species in each marsh were recorded. It is important to note that these ratings did not give any indication of actual amounts of plant material present in the ponds but merely ranked the marshes according to the relative amounts present. In 1967, samples of plant material were harvested. A quadrat 0.5 meter on a side was placed at random in the marsh and all the plant material present within the quadrat, both submergent and emergent, was harvested and its dry weight determined. Yields were calculated as total production per marsh.

The relative ratings made each year provided information on the persistence of the introduced species in the various marshes so that the influence of the treatments imposed might at least be inferred. Thus, differences in vegetation present were observed by the end of the 1962 season. Of the submergent species, water naiad was the most widely distributed, but sago pondweed and water celery were present in most of the marshes. Chara, on the other hand, was limited to the deeper marshes. Burreed and water smartweed had almost completely disappeared by the end of the 1962 season. Hard-

stem bulrush was present in some of the marshes, but its presence or absence was apparently determined by the activity of muskrats rather than any characteristic of the marsh.

At the end of the 1963 season the introduced submergent species remained as in 1962. Among the emergent species, however, hardstem bulrush and wild rice had essentially disappeared from the 2½- and 3-foot-deep marshes. Burreed and water smartweed made a good recovery in 1963 compared with earlier stands.

Visual ratings in 1964 indicated water naiad remained widely distributed and not much influenced by water depth. Both water celery and chara were most abundant in the 2- to 3-foot-deep marshes. During this season, hardstem bulrush spread rapidly in the shallower marshes.

In 1965, the density of the submerged species was higher than it had been in 1964. The emergent species continued to be most prevalent at the shallower depths. By 1965, burreed had essentially disappeared from the deeper marshes along with hardstem bulrush and wild rice which had disappeared previously.

The distribution of chara, sago pondweed and water celery in 1966 remained about as it had in previous years. Water naiad which had been widely distributed in previous years was found in 1966 in only three of the deeper marshes. Of the emergent species, hardstem bulrush was the dominant one present and it was most prevalent in the shallower marshes. Other emergent species were found in only small amounts and were most prevalent in the shallow marshes.

The ratings in 1967 revealed no substantial change in the distribution of either the submerged or the emergent species compared with observations in 1966. Thus, there were some indications that by the 1966 and 1967 seasons the vegetation was becoming stabilized in the marshes with chara being the dominant introduced submerged species and distributed generally throughout the marshes. Chara was also abundant in the water supply marsh and the main water supply canal, and it is not known how much of its distribution in 1967 was a result of the original plantings. Since chara is characteristic of alkaline waters, its dominance in these waters was to be expected. Hardstem bulrush was the dominant emergent species and was confined largely to the shallower marshes. The quantity of wild rice seemed to fluctuate from year to year and was possibly more influenced by wildlife activity than by any other ecological factor associated with the marshes themselves.

A rather substantial number of invading species were found in the marshes throughout the experiment. It became increasingly dif-

TABLE 12. YIELDS OF WILD RICE GRAIN HARVESTED FROM THE EXPERIMENTAL MARSHES IN 1960 AND 1961 IN RELATION TO TYPE OF TREATMENT WITH LIMESTONE AND ORGANIC MATTER

Water depth (feet)	Yield (grams)	
	1960	1961
Limestone: none — Organic matter: none		
1.0	2.18	13.00
1.5	0.79	4.00
2.0	0.87	2.30
2.5	1.41	2.50
3.0	1.54	2.50
Mean	1.36	4.86
Limestone: none — Organic matter: high		
1.0	45.60	10.00
1.5	2.33	3.00
2.0	53.35	2.50
2.5	9.28	7.00
3.0	3.78	13.75
Mean	22.87	7.25
Limestone: high — Organic matter: none		
1.0	5.19	3.33
1.5	0.67	1.60
2.0	0.63	2.50
2.5	0.40	8.00
3.0	1.92	4.00
Mean	1.76	3.89
Limestone: high — Organic matter: high		
1.0	16.68	25.00
1.5	55.04	11.00
2.0	15.33	3.40
2.5	3.02	7.50
3.0	6.81	15.00
Mean	19.37	12.38

ficult to remove these species, and in the last few years no attempt was made to remove them, so that a true vegetative equilibrium in the marshes may have been in the process of becoming established. The chief invading plants were several of the pondweeds *(Potamogeton)*.

FACTORS INFLUENCING PLANT GROWTH Yields of wild rice harvested from the marshes in 1960 and 1961 were influenced by organic matter treatment and the water depth (Tables 12 and 13). Addition of limestone to the marsh soils did not influence these yields, however. Where organic matter had been added yields were very much higher

TABLE 13. MEAN YIELDS OF WILD RICE GRAIN HARVESTED FROM THE EXPERIMENTAL MARSHES IN 1960 AND 1961 IN RELATION TO LIME, OGANIC MATTER AND WATER DEPTH

Factor	Value	Mean yield (grams)	
		1960	1961
Lime	High	12.12	6.06
	Low	10.57	8.14
Organic matter	High	1.66	4.38
	Low	21.12	9.82
Water depth (feet)	1.0	17.91	12.83
	1.5	14.71	4.90
	2.0	17.55	2.54
	2.5	3.53	6.25
	3.0	3.51	8.81

in 1960 and about double in 1961. The added organic matter undoubtedly contributed nutrients, especially nitrogen, to the growing plants and this contribution was especially significant the first year. Yields of wild rice were related inversely to water depth. Since these soils had initially had a high pH, it is not surprising that plant growth was not influenced by lime additions.

The total yield of plant material harvested in 1967 from each marsh is given in Tables 14 and 15 and shows that the influence of added organic matter was much less than that recorded earlier in the experiment. Limestone additions had no influence on yields. Total plant growth in the last year was inversely related to water depth which appeared to be the one imposed variable that was related to plant growth in any substantial way.

A statistical summary is given in Table 16 where either the yields of wild rice obtained or the vegetative indexes tabulated were related to the variables imposed. The tabulation reveals that water depth

TABLE 14. YIELDS OF PLANT MATERIAL HARVESTED FROM THE EXPERIMENTAL MARSHES DURING SEASON OF 1967 IN RELATION TO TYPE OF TREATMENT WITH LIMESTONE AND ORGANIC MATTER

Water depth (feet)	Yield (kilograms per marsh)
Limestone: none — Organic matter: none	
1.0	87.9
1.5	171.8
2.0	110.1
2.5	116.7
3.0	61.6
Mean	109.6
Limestone: none — Organic matter: high	
1.0	258.9
1.5	74.0
2.0	67.4
2.5	41.1
3.0	55.1
Mean	99.3
Limestone: high — Organic matter: none	
1.0	95.3
1.5	93.7
2.0	81.4
2.5	64.1
3.0	47.7
Mean	76.4
Limestone: high — Organic matter: high	
1.0	223.5
1.5	192.3
2.0	..
2.5	39.4
3.0	32.1
Mean	121.8

TABLE 15. MEAN YIELDS OF PLANT MATERIAL HARVESTED FROM THE EXPERIMENTAL MARSHES DURING THE GROWING SEASON IN 1967 IN RELATION TO LIME, ORGANIC MATTER AND WATER DEPTH

Factor	Value	Mean yield (kilograms per marsh)
Lime	Low	104.5
	High	99.1
Organic matter	Low	93.0
	High	110.6
Water depth (feet)	1.0	166.4
	1.5	133.0
	2.0	86.3
	2.5	65.3
	3.0	49.1

was related to the indices of vegetative production throughout the study. It also shows that liming these soils had no effect on plant growth. Addition of organic matter increased plant growth early in the experiment, but its effect had diminished by 1967. The observations on plant production in these marshes were fairly subjective and undoubtedly not consistent from year to year. Nonetheless, the relationships observed and tabulated in Table 13 are very likely meaningful and thus give a reasonably true reflection of the influence of organic matter additions, lime additions and water depth on plant growth in this particular environment.

In addition to the variables described, multiple regression equations were calculated showing the relation between indices of plant growth and the various physical and chemical characteristics of the water and the bottom soils that were measured in these marshes. These equations were calculated by incorporating each factor in a stepwise fashion until all the variables that were related to differences in plant growth were included. As shown in Table 17, over 70 per cent of the variability in plant growth could be accounted for by these equations. In addition the amount of the variability accounted for by the addition of the first four factors is also given. In some cases a surprisingly large amount of the variability was accounted for by the first four terms. No single variable that was related to differences in plant growth appeared in all of the equations. Several, such as organic matter content of the bottom soil, dissolved oxygen in the water and the magnesium content of the bottom soil, appeared in several equations. It is surprising that some of the values

Table 16. Summary of Statistical Evaluations of Relationship Between Measures of Vegetative Production and Water Depth, Organic Matter and Lime

Year	Measure	Significance of *F* values		
		Water depth	Organic matter	Lime
1960	Wild rice yield	ns	**	ns
1961	Wild rice yield	*	**	ns
1964	Vegetative index	*	**	ns
1965	Vegetative index	*	ns	ns
1966	Vegetative index	*	ns	ns
1967	Vegetative index	*	ns	ns

*Significant at odds of 9:1.
**Significant at odds of 19:1.

such as the extractable magnesium and potassium content of the soil were found related to plant growth since they varied over such a narrow range. In addition the magnesium content of these soils was sufficiently high that no effect on plant growth would be expected normally.

These regression equations are presented without any thought that the observed variations in plant growth can be explained. They are presented to illustrate the complexity of attempting to understand the factors that do cause variations in plant growth in an aquatic environment. It is difficult to explain why some of the variables contributed significantly to the regression equations, extractable magnesium and potassium being instances in point. In other cases, a variable was positively related in one season and negatively related in another season to differences in plant growth. The organic matter content and the extractable iron content are examples. Thus, while certain relationships appear to exist, at the present time it does not seem reasonable to single out any specific factor or set of factors as the one that is most responsible for the observed variations in plant growth. Indeed, it is entirely possible that the variables measured were strongly correlated with some unmeasured factor that influenced plant growth. This of course would result in the measured variables being included in a regression equation and, therefore, cannot be precluded in the data given here. Any further clarification of the factors responsible for variations in plant growth must come from further study of this particular environment.

Factors that seem to be good possibilities for study include the fate of iron in these systems, particularly the ferrous form (Fe^{2+}).

Table 17. Regression Equations Calculated from Chemical and Physical Measurements Made on the Marshes

Year	Equation*	Percentage variation in Y accounted for by first four terms	Percentage variation in Y accounted for by all terms
1960	$Y = 11.5 + 0.70$ (t.a.) $- 0.18$ (Fe) $+ 3.01$ (P) $- 0.73$ (K) $+ 0.009$ (Mg) $- 5.30$ (t.) $+ 5.2$ (o.c.)	63	72
1961	$Y = -513.8 - 0.89$ (N) $+ 0.014$ (Mg $+ 1.2$ (o.m.) $+ 40.5$ (water pH) $- 6.5$ (t.) $- 6.0$ (o.c.) $+ 0.27$ (Mn) $+ 0.25$ (t.a.) $- 16.3$ (P) $+ 41.8$ (soil pH)	33	78
1964	$Y = 144.8 + 18.1$ (o.m.) $- 23.5$ (water pH) $+ 3.7$ (t.) $+ 0.84$ (K) $- 0.48$ (N)	81	83
1965	$Y = 624.8 - 0.83$ (t.a.) $- 0.323$ (Mg) $- 7.31$ (o.m.) $- 1.16$ (Al) $- 53.4$ (soil pH) $+ 3.1$ (o.c.) $- 32.4$ (water pH) $- 0.00068$ (Ca) $+ 0.11$ (Fe) $- 1.34$ (N) $+ 0.67$ (K) $+ 0.87$ (t.)	50	75
1966	$Y = 302.2 - 18.7$ (soil pH) $- 0.28$ (K) $- 0.026$ (Fe) $- 7.9$ (o.c.) $+ 0.55$ (Al) $- 0.044$ (Mn) $+ 0.00017$ (Ca) $- 0.85$ (o.m.)	45	71

*Y = measure of plant growth
t. = water temperature
t.a. = Total alkalinity of water
o.c. = oxygen content of water
o.m. = organic matter
Other symbols follow standard chemical usage.

Whether some form of siderite ($FeCO_3$) is the ultimate fate of soluble iron can only be inferred at this time. The oxidation state of the soil at the soil-water interface and its influence on the concentrations of nitrate and soluble iron remain to be determined. Diffusion of soluble constituents into the water from the soil, and the reverse, may have some influence on productivity. Presently, no information on this possibility is available. Finally, the reduction of manganese to its Mn^{2+} form in these systems and the role iron may play in this reduction have not been studied.

The fluctuations in total alkalinity of the water from year to year are difficult to explain, but it does seem likely that the carbonate-bicarbonate system was the controlling influence in these marshes. As long as the alkalinity remains high, toxic levels of elements such as iron and manganese are not likely to occur although this relationship has not been definitely determined. Likewise, accumulation of sulfide, which is extremely toxic to plant growth, cannot be precluded from these environments although there was no evidence of its presence. This factor needs to be considered especially in marshes on materials more acidic than the ones involved in this study.

The complete energy mass of the marshes may be important in determining their plant productivity. The unmeasured inputs and outgoes in such a system are enormously complex and difficult to analyze. Before a complete understanding of the ecology of such marshes is reached, however, the complete biotic turnover will need to be studied.

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DISTRIBUTION OF LARVAL WALLEYES AND YELLOW PERCH IN A BAY OF ONEIDA LAKE AND ITS RELATION TO WATER CURRENTS AND ZOOPLANKTON[1]

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ABSTRACT

Walleye and yellow perch larvae were collected in Billington Bay on four days in 1967 to determine their distribution, and both zooplankton abundance and water currents were measured. Walleye larvae were progressively concentrated in the western third of the bay as the season advanced, but the distribution of perch larvae varied in response to changing winds. Larval walleyes were more abundant at a depth of 3 meters than at 2 meters when wind velocity exceeded 5 meters per second, but yellow perch were always more abundant at 2 meters. By altering depth distribution in response to wind, walleyes avoided the strong surface currents associated with high winds, and their distribution remained stable. Currents were usually westerly in direction at 2 meters and deeper, but surface currents closely paralleled wind direction. Yellow perch were nearer the surface and their distribution reflected the prevailing wind conditions by changing from day to day. Zooplankton distributions were variable from day to day and were not easily related to water currents in the bay. Although distributions of walleye and yellow perch larvae were usually different, a high, positive partial correlation was noted between the two species when several environmental factors were held constant. Few significant correlations existed between larvae and zooplankton, and no relation between abundance of potential food organisms and fish larvae could be recognized.

Sampling programs to examine the distribution and abundance of larval fish have been undertaken on Oneida Lake each year since 1960. Distribution of walleye *(Stizostedion vitreum vitreum)* larvae was described by Houde and Forney (in press) who noted that larval walleyes concentrated in certain south shore bays each year. Yellow perch *(Perca flavescens)* larvae were more widely distributed than walleye larvae (Noble, 1968), and no tendency to form concentrations within bays was observed. Differences in distribution of the two species were partly due to the hatchery origin of many walleye larvae (Houde and Forney, in press) in contrast to naturally produced yellow perch. However, the progressive increase in abundance

[1]Derived from a Ph.D. thesis submitted to the Graduate School at Cornell University in 1968. Assistance in all phases of the study was given by Dr. John L. Forney. Drs. John Barlow and LaMont Cole criticized the thesis manuscript which was the source of this paper. Dr. Richard Noble helped throughout the study and criticized the manuscript in the later stages of its preparation. Larry Male of the Cornell University Biometrics Unit gave advice on statistical treatment of data as well as help in the use of Cornell computer facilities. Charles Taylor and Herbert Haight helped build much of the equipment used. In addition, Mr. Taylor provided valuable assistance in the field. Financial support for this research was provided by New York Federal Aid to Fish and Wildlife Restoration Project F-17-R.

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Figure 1. Map of Oneida Lake showing location of Billington Bay.

of walleyes in the bays suggested that some behavior mechanisms were operating, perhaps in conjunction with hydrographic factors.

One objective of this study was to investigate the factors which caused concentration of walleye larvae in bays. In 1967, Billington Bay (Figure 1) was selected for a detailed study of distribution of walleye and perch larvae because high densities of walleye larvae had been found there in previous years. In addition to collections of fish larvae, zooplankton was sampled to relate possible effects of food abundance to distribution of both walleye and perch larvae. Water currents were measured in the bay to evaluate their effect as a distributional mechanism for larvae.

Walleyes and yellow perch unually hatch in early May. Their larvae are similar in many respects, but in Oneida Lake perch larvae are about 6.0 millimeters in total length at hatching while walleyes average 7.0 to 7.5 millimeters. Larvae of both species were described by Norden (1961). Both species are photopositive during their larval stages. Yolk absorption is complete in yellow perch of 7.0 millimeters in total length, but in walleyes some yolk persists until they are 9.5 millimeters long. Walleye larvae averaged 8.9 millimeters in total length when the study was begun on May 22, and 10.7 millimeters on June 2, the last sampling day. Length-frequency distributions indicated that little recruitment of newly hatched walleyes took place after the first sampling date, but that recruitment of yellow perch larvae occurred at least until May 29. Larval perch averaged about 6.0 millimeters in total length on May 22, and about 9.0 millimeters by June 2, but a relatively wide range of lengths was observed on each date.

METHODS

Larval fish were sampled with meter nets of No. 00-mesh nylon towed for 2.5 minutes at a constant engine speed (approximately 4.1 kilometers per hour) by a 22-foot inboard boat. Depth of tow was set by the angle and length of the tow rope. Zooplankton collections were made with open-tube Clarke-Bumpus samplers fitted with No. 10 nylon nets. Plankton samplers were mounted in the center of the meter-net ring, and their flow meters served to determine the volumes strained by both types of gear. Water currents were measured by free-drifting drogues as described by Houde (1968) during the time samples were being collected.

Five sampling stations in Billington Bay (Figure 2) were spaced over as wide an area of the bay as practical, considering the maneuverability of the boat and gear. Depths at stations ranged from 3.7 meters at Station 1 to 7 meters at Station 5. Meter nets were towed at 2-meter and 3-meter depths on four days and one night. Replicated samples were taken at each station to estimate residual variation. An additional pair of samples was collected at 3.6 meters from Station 4 and at 4.6 meters from Station 5. Complete series of larval fish and zooplankton samples were collected in 2 hours on May 22, 24 and 29 and June 2. Another complete series of collections was made at night on June 2 to provide a day-night comparison of distribution.

Fish and zooplankton samples were preserved with formalin and brought to the laboratory for sorting and counting. Zooplankton was counted, from three separate 1-cubic-centimeter aliquots of the sample concentrate, in a Sedgewick-Rafter counting chamber. Num-

Figure 2. Map of Billington Bay showing location of sampling stations used.

bers per liter of lake water strained were recorded for each genus. The most numerous species of zooplankton were identified, but organisms were not counted by species. Total lengths of larval walleyes were measured with an ocular micrometer mounted in a binocular microscope.

Distributions were examined by treating the data in factorial analyses of variance. Factors were days, stations and depths. Although the three main effects were important in describing distribution of organisms, interaction terms of the analyses were valuable in helping to explain changes in distribution. Before analyses of variance were carried out, catches were transformed to common logarithms for all organisms except walleye larvae, which were transformed by taking logarithms of catch plus one because some zero catches were present. Transformation succeeded in stabilizing variance and in eliminating correlations between mean and variance.

RESULTS

The observations with respect to water currents in the bay and the distribution of larvae and zooplankton are presented separately.

Billington Bay Currents

Drogue releases in 1965 and 1966 had indicated that a weak clockwise eddy was present within the bay at a depth of 2 meters when winds originated from the west or northwest. Currents at 1 meter were deflected to the right of the wind direction, and velocities of both the 1- and 2-meter currents decreased from a maximum at the bay mouth to a minimum near the western perimeter of the bay. Drogues were released near the sampling stations in the bay on each day in 1967. Two days of easterly winds and two days of westerly winds were chosen to examine the possible differences in distribution of larval fish due to currents.

Winds were light northwest on May 22 and moderate northwest on June 2. Surface currents traveled east-southeast on both days, but subsurface currents were directed progressively to the right as depth increased (Table 1). Currents at 2 and 3 meters moved west near Stations 1 and 2, but near Stations 4 and 5 they differed little in direction from surface currents. A clockwise eddy was present at both 2 and 3 meters on June 2 when wind velocity averaged 5.4 meters per second, but it was more developed at 3 meters than at 2 meters on May 22 when winds averaged only 2.9 meters per second. Winds were east-southeast on May 24 and 29, with an average velocity of 8.9 meters per second on the former and 3.6 meters per second on the latter date. On both days currents moved west at most stations and

Table 1. Water Currents Measured Near Stations Where Larval Fish and Zooplankton Were Collected in Billington Bay During 1967*

Date	Wind		Depth in meters	Water current									
				Station 1		Station 2		Station 3		Station 4		Station 5	
	Velocity	Direction		Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction
May 22	290	315	0.0	5.14	103	..	..	..	..	14.35	102	..	..
			1.0	0.80	137	..	..	..	..	5.10	145	..	..
			2.0	0.30	158	..	..	..	..	4.45	106	..	..
			3.0	0.35	226	..	..	..	..	4.45	106	..	..
			3.6	..	..	..	..	..	..	2.48	135	..	..
			5.5	..	..	..	..	..	..	..	..	5.20	85
May 24	890	113	0.0	16.35	276	..	..	..	..	13.24	254	..	..
			1.0	4.50	2	..	..	..	..	4.45	290	..	..
			2.0	2.25	86	1.80	309	..	..	4.95	294	..	..
			3.0	..	..	2.85	329	..	..	4.95	294	..	..
			3.6	..	..	..	..	..	..	3.40	306	..	..
			5.5	..	..	..	..	..	..	..	..	2.40	138
May 29	360	113	0.0	..	..	17.58	349	..	..	11.38	3	..	..
			1.0	..	..	2.00	334	4.45	298	3.15	330	..	..
			2.0	..	..	1.60	231	..	..	2.50	273	..	..
			3.0	..	..	3.20	251	..	..	2.60	233	..	..
			3.6	..	..	..	..	..	..	4.90	189	..	..
			5.5	..	..	..	..	..	..	..	..	4.00	152
June 2	540	315	0.0	..	..	..	..	..	..	22.73	126	..	..
			1.0	1.85	176	..	..	5.30	144	10.75	126	..	..
			2.0	5.00	312	..	..	1.45	316	6.90	116	..	..
			3.0	..	..	4.45	316	1.40	278	4.00	116	..	..
			3.6	..	..	..	..	..	..	0.80	324	..	..
			5.5	..	..	..	..	..	..	..	..	2.15	30

* Velocity in centimeters per second; direction in degrees from north.

depths (Table 1). Water at 2 and 3 meters flowed directly west on May 29, but it followed the contours of the bay on May 24. Velocities on May 29 were about the same near Stations 1 and 2 as they were near Stations 4 and 5, but on May 24 they were greater near Stations 4 and 5.

Mean current velocities for the four days were less near stations along the western border of the bay then near its center. Currents near Stations 4 and 5 averaged 4.00, 4.70 and 5.85 centimeters per second at depths of 3, 2 and 1 meters, respectively, but those near Stations 1 and 2 averaged only 2.71, 2.29 and 2.45 centimeters per second, respectively, for the same depths.

Distrirution of Larvae in Billington Bay

Differences in distribution of perch and walleye larvae in the bay were apparent upon examination of the catch (Table 2). Total catches of walleyes increased on each sampling date due to concentration of larvae near Stations 1 and 2 (Figure 3) in the western half of Billington Bay, while catches at the other stations decreased. Yellow perch larvae were consistently more abundant than walleye larvae (Table 2), but there were no trends at any of the stations (Figure 4). Highest catches varied among stations from day to day, presumably in response to changing wind and water current regimes. Geometric mean catches of walleye larvae per 100 cubic meters at each station, over all days and depths, were: Station 1 — 25.50; Station 2 — 26.39; Station 3 — 7.89; Station 4 — 3.87; and Station 5 — 3.42. Mean catches of yellow perch for the same stations were 323.10, 276.40, 241.20, 206.75 and 234.70, respectively. The nature of the walleye distribution suggested that the population was being concentrated within the western third of the bay and that it probably was confined to the bay. There was no evidence to suggest that yellow perch formed a separate population in the bay, but catches probably were from a lake population, parts of which were available in Billington Bay on each sampling date.

Analyses of variance confirmed the distributional pattern observed and added additional insight into some characteristics of distribution for both species (Table 3). Differences in catches were highly significant among stations for walleye larvae but barely significant for yellow perch ($P = .05$). Catches of perch differed significantly among stations only because the pooled catches over days and depths were greater at Station 1 than at Station 4 (according to Tukey's *hsd* procedure as given by Steel and Torrie, 1960). Day by station interaction was highly significant for walleye larvae due to concentration at Stations 1 and 2 (Figure 3). The interaction also was

TABLE 2. CATCHES (PER 100 CUBIC METERS) OF WALLEYE AND YELLOW PERCH LARVAE IN REPLICATED HAULS AT TWO DEPTHS AND FIVE STATIONS IN BILLINGTON BAY

Date	Station									
	1		2		3		4		5	
	2 meters	3 meters	2 meters	3 meters	2 meters	3 meters	2 meters	3 meters	2 meters	3 meters
Walleye										
May 22	6.9	23.5	19.4	3.0	5.3	5.3	18.9	9.5	7.0	3.5
	23.2	27.1	11.3	15.6	10.0	5.7	18.0	4.5	16.3	12.2
May 24	10.6	36.3	2.4	24.4	2.6	5.3	3.0	6.0	2.3	1.2
	5.1	9.0	7.1	10.6	2.6	13.3	0.0	2.6	2.4	3.6
May 29	19.7	23.9	45.6	17.1	4.3	7.2	1.5	4.4	2.8	1.4
	26.2	24.0	24.9	35.2	4.8	3.2	5.5	4.1	5.8	1.5
June 2	89.5	53.9	359.8	51.2	21.6	51.3	0.0	1.5	0.0	1.5
	107.4	47.6	148.9	182.3	0.0	49.4	0.0	0.0	0.0	0.0
June 2*	100.0	56.3	273.0	695.0	29.6	9.4	6.4	5.1	0.0	0.0
	61.8	75.0	299.2	361.7	78.1	4.2	5.5	0.0	3.8	0.0
Yellow Perch										
May 22	123.0	87.1	309.7	186.1	404.6	229.5	1022.4	401.1	206.4	237.6
	337.8	250.2	258.1	209.9	451.0	385.1	784.6	576.0	403.9	301.9
May 24	1,750.3	568.3	146.2	237.6	509.4	331.6	249.0	363.0	661.4	439.0
	913.5	752.7	804.2	503.1	541.2	677.9	399.8	476.6	707.4	618.4
May 29	476.2	279.5	460.2	250.8	115.9	55.1	41.6	25.2	49.6	17.9
	1,176.9	376.7	441.5	311.0	62.6	30.5	51.9	13.7	60.0	29.3
June 2	174.1	72.3	335.6	82.2	337.6	283.6	540.1	327.7	705.4	539.0
	299.1	95.2	300.6	187.9	317.6	317.6	156.8	140.0	533.4	302.5
June 2*	332.3	501.3	86.2	331.5	131.8	87.4	50.2	90.1	631.2	183.8
	280.9	416.2	88.6	371.9	280.4	64.2	139.3	56.0	933.2	115.9

* Night

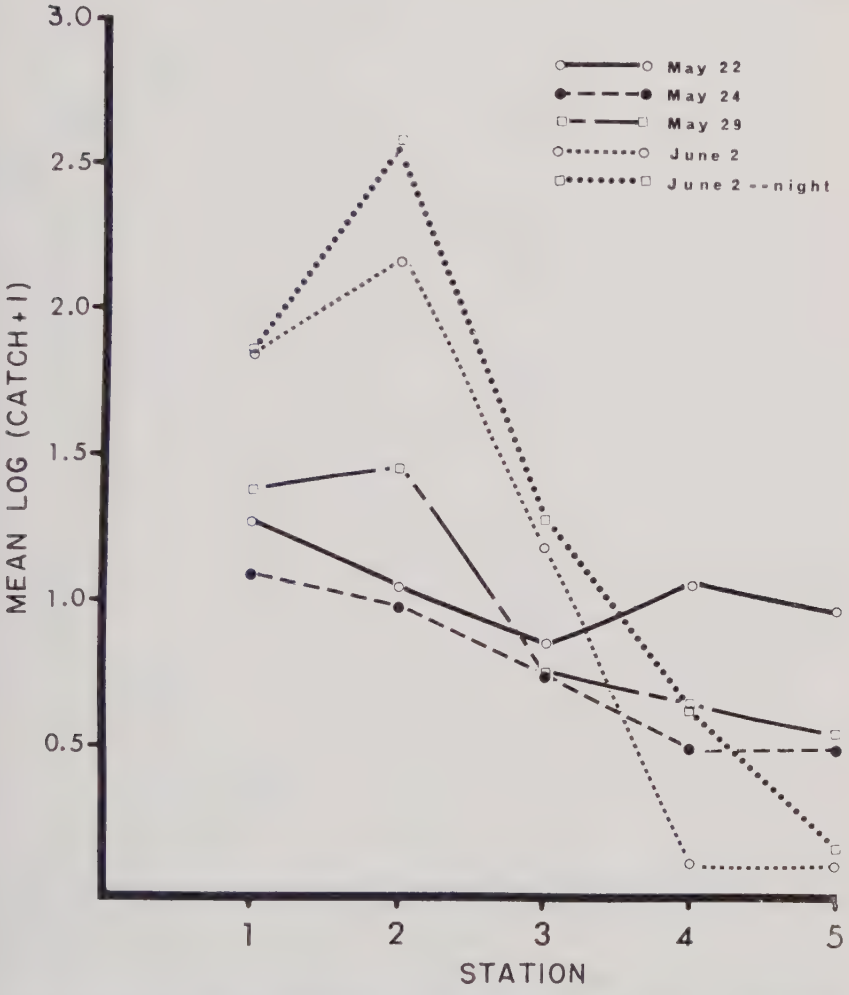

Figure 3. Day by station interaction for catches of walleye larvae in Billington Bay on four days and one night at five stations.

highly significant for yellow perch, but it was due to a more general inconsistency in distribution among stations (Figure 4).

Depth distribution of each species and its probable effect on horizontal distribution within the bay were clarified in the analyses. No significant difference was observed for the mean numbers of walleye larvae collected at 2 and 3 meters depth, considering samples taken over all days and stations. Geometric mean catches of 8.56 and 10.11 per 100 cubic meters were made at depths of 2 and 3 meters, respectively. For yellow perch, catches were significantly higher

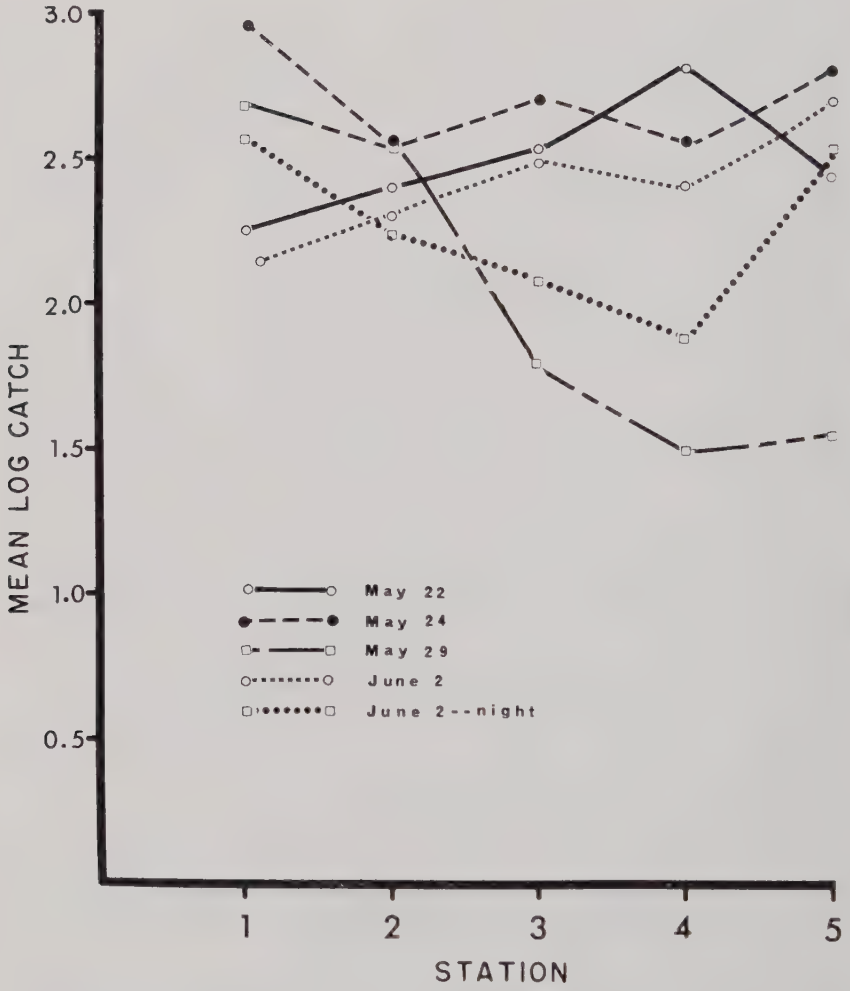

Figure 4. Day by station interaction for catches of yellow perch larvae in Billington Bay on four days and one night at five stations.

at 2 meters than at 3 meters ($P < .005$). A geometric mean catch of 317.20 per 100 cubic meters was obtained at 2 meters while a mean of only 202.40 occured in samples at 3 meters. Although there was no significant difference in the mean catch of walleyes at the two depths for samples over all days, the day by depth interaction was significant ($P < .05$) due to different relative proportions of larvae caught at the two depths among days. There was no significant interaction of day by depth for yellow perch, emphasizing the relatively stable nature of the depth distribution for this species on the

TABLE 3. FACTORIAL ANALYSES OF VARIANCE FOR WALLEYE AND YELLOW PERCH LARVAE COLLECTED IN BILLINGTON BAY ON FOUR DATES IN 1967

Source of variation	Degrees of freedom	Sum of squares	Mean square	F§
Walleye†				
Days	3	1.1770	0.3923	5.63***
Stations	4	11.7875	2.9469	42.30***
Day x stations	12	7.7217	0.6435	9.24***
Depth	1	0.1025	0.1025	1.47
Day x depth	3	0.6879	0.2293	3.29*
Station x depth	4	0.4716	0.1179	1.69
Day x station x depth	12	1.3449	0.1121	1.61
Residual	40	2.7866	0.0697	
Yellow perch‡				
Days	3	5.0097	1.6699	5.05***
Stations	4	3.5090	0.0877	2.65*
Day x stations	12	6.7338	0.5611	16.97***
Depth	1	0.7616	0.7616	23.03***
Day x depth	3	0.1900	0.0633	1.91
Station x depth	4	0.0673	0.0168	0.51
Day x station x depth	12	0.1941	0.0162	0.49
Residual	40	1.3229	0.0331	

§ Probability: $*P<.05$; $**P<.025$; $***P<.005$.

† Based on logarithms of catch plus one per 100 cubic meters.

‡ Based on logarithms of catch per 100 cubic meters.

four days. The day by depth interactions (Figure 5) suggested a difference in behavior of the two species. The majority of yellow perch larvae consistently remained near the surface, but walleyes were most abundant at 2 meters when the wind was light on May 22 and May 29, and at 3 meters on the two days with stronger wind. An inverse relationship existed between wind velocity and the relative abundance of walleyes at 2 meters (Figure 6). At wind velocities exceeding approximately 5 meters per second, the proportion of walleyes became greater in catches at 3 meters than at 2 meters. Although there was a tendency for yellow perch catches to decrease at 3 meters on windy days, the catch at 2 meters always exceeded that at 3 meters. By altering their depth distribution, some walleye larvae avoided the turbulence and swift currents associated with water near the surface when wind velocities were high. Currents at depths of between 2 and 3 meters usually were directed west and had lower velocities than currents near the surface. Yellow perch

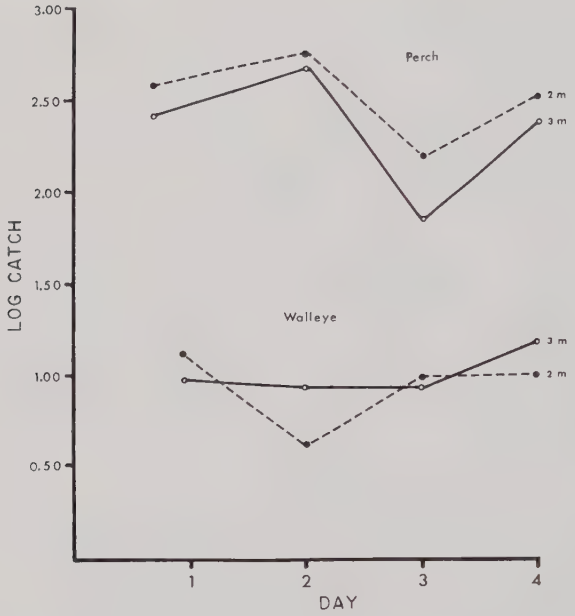

Figure 5. Day by depth interaction for catches of walleye and yellow perch larvae collected on four days at 2 and 3 meters in Billington Bay.

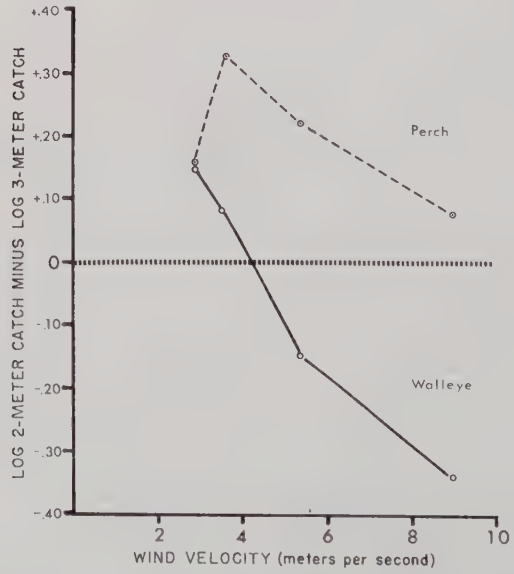

Figure 6. Relation between catch at two depths and wind velocity for walleye and yellow perch collected at 2 and 3 meters on four days in Billington Bay.

TABLE 4. FACTORIAL ANALYSES OF VARIANCE FOR COMPARISON OF DAYTIME AND NIGHTTIME CATCHES OF WALLEYES AND YELLOW PERCH IN BILLINGTON BAY ON JUNE 2-3, 1967

Source of variation	Degrees of freedom	Sum of Squares	Mean square	F§
Walleye				
Time of day	1	0.4658	0.4658	4.55*
Stations	4	29.3314	7.3328	71.70***
Time x station	4	0.4138	0.1035	1.01
Depth	1	0.0457	0.0457	0.45
Time x depth	1	0.4943	0.4943	4.83*
Station x depth	4	0.0910	0.0227	0.22
Time x station x depth	4	1.8005	0.4501	4.40*
Residual	20	2.0454	0.1023	
Yellow perch				
Time of day	1	0.2046	0.2046	7.18*
Stations	4	0.9501	0.2375	8.34***
Time x station	4	1.0885	0.2721	9.55***
Depth	1	0.2602	0.2602	9.13**
Time x depth	1	0.0596	0.0596	2.09
Station x depth	4	0.3168	0.0792	2.78
Time x station x depth	4	0.8460	0.2115	7.42***
Residual	20	0.5698	0.0285	

§ Probability: $*P<.05$; $**P<.01$; $***P<.005$.

larvae remained exposed to the stronger currents near the surface, which flowed in the same direction as the wind, and the population appeared to respond to daily changes in water-current direction caused by changing winds (Figure 4).

A complete series of samples was collected during the afternoon and night of June 2-3 for a comparison of daytime and nighttime catches. Daytime collections were made from 3:30 to 5:30 p.m., and those at night were made from 11:00 p.m. to 1:15 a.m. Winds during the day had been moderate northwest but had decreased to zero by 9:00 p.m. The lake was calm at night, the air temperature was 50° F. and there was a bright, starlit sky.

Untransformed catches of walleye and yellow perch larvae per 100 cubic meters were tabulated (Table 2) and subsequently treated by analyses of variance similar to those used for the four days' collections, but with the factor, time of day, substituted for days (Table 4). Results of the analyses showed that the distribution of walleyes remained more stable than that of yellow perch. The size of catches differed significantly between day and night for both

species. Walleye larvae increased in the catches from a geometric mean of 12.17 per 100 cubic meters during the day to one of 20.00 at night, probably due to decreased avoidance of gear after dark. Perch larvae decreased in abundance from a geometric mean of 255.60 per 100 cubic meters during the day to one of 183.90 at night. This decrease was related to a change in distribution of the larvae, including some transport out of the sampling area, as indicated by the significant time of day by station interaction ($P < .005$) and examination of the relative catch at each station for each collection time (Table 2). The distribution of walleye larvae remained stable between times, with the highest catches occurring at Stations 1 and 2.

Mean catches for pooled day and night samples at 2 and 3 meters were not significantly different for walleye larvae, but yellow perch larvae were more abundant at 2 meters (Tables 2 and 4). A significant time of day by depth interaction was observed only for walleye catches, caused by a great increase in the catch at 2 meters from a geometric daytime mean of 10.20 per 100 cubic meters to one of 27.93 at night. A corresponding increase in the walleye catch did not occur at 3 meters. The increase of walleye larvae near the surface may have been a photopositive response to bright starlight or a movement toward the surface related to decreased wind velocity and surface turbulence at night.

Zooplankton Distribution in Billington Bay

Distribution of four common zooplankton genera and copepod nauplii in the bay was examined by methods similar to those used to compare distributions of fish larvae. A single species was dominant in each genus and the results reflected the distribution of the species. These were *Diaptomus minutus*, *Cyclops biscuspidatus thomasi*, *Epischura lacustris* and *Daphnia galeata mendotae*.

Abundance of every organism varied among days ($P < .005$), and significant day by station interactions ($P < .005$) were observed for each organism (Table 5) due to day to day changes in horizontal distribution. Differences in abundance at the two depths were significant for *Cyclops*, *Epischura* and *Daphnia*. *Cyclops* was always most abundant at 2 meters, geometric mean catches being 25.09 per liter at 2 meters and 20.36 per liter at 3 meters. *Daphnia* also was more abundant at 2 meters, the mean catches being 5.83 and 4.55 per liter at 2 and 3 meters, respectively. A higher catch of *Epischura* was made each day at 3 meters than at 2 meters, with means of 3.42 and 2.74 per liter, respectively. Day by depth interactions proved significant only for *Diaptomus* and *Epischura*. Depth

TABLE 5. FACTORIAL ANALYSIS OF VARIANCE§ FOR FIVE GROUPS OF ZOOPLANKTON IN SAMPLES COLLECTED IN BILLINGTON BAY ON FOUR DATES IN 1967.

Source of variation	Degrees of freedom	Sum of squares	Mean Square	F†
Cyclops				
Days	3	0.9170	0.3057	14.52***
Stations	4	0.2049	0.0512	2.43
Day x station	12	1.7580	0.1465	6.96***
Depth	1	0.1648	0.1648	7.83**
Day x depth	3	0.0374	0.0125	0.59
Station x depth	4	0.0412	0.0103	0.49
Day x station x depth	12	0.2445	0.0204	0.97
Residual	40	0.8421	0.0210	
Diaptomus				
Days	3	0.3858	0.1286	6.40***
Stations	4	1.2520	0.3130	15.56***
Day x station	12	1.0649	0.0887	4.41***
Depth	1	0.0028	0.0028	0.14
Day x depth	3	0.1795	0.0598	2.97*
Station x depth	4	0.0403	0.0101	0.50
Day x station x depth	12	0.2102	0.0175	0.87
Residual	40	0.8043	0.0201	
Epischura				
Days	3	2.2174	0.7391	45.66***
Stations	4	3.2745	0.8186	50.57***
Day x station	12	5.1608	0.4301	26.57***
Depth	1	0.1832	0.1832	11.32***
Day x depth	3	0.1810	0.0603	3.73**
Station x depth	4	0.0182	0.0046	0.28
Day x station x depth	12	0.3296	0.0275	1.70
Residual	40	0.6475	0.0162	
Nauplii				
Days	3	3.5665	1.1888	66.78***
Stations	4	0.1092	0.0273	1.53
Day x station	12	1.3997	0.1166	6.55***
Depth	1	0.0194	0.0194	1.09
Day x depth	3	0.1282	0.0427	2.40
Station x depth	4	0.1880	0.0470	2.64*
Day x station x depth	12	0.2432	0.0203	1.14
Residual	40	0.7121	0.0178	
Daphnia				
Days	3	4.7558	1.5853	77.73***
Stations	4	0.7259	0.1815	8.90***
Day x station	12	1.3680	0.1140	5.59***
Depth	1	0.2328	0.2328	11.41***
Day x depth	3	0.0708	0.0236	1.16
Station x depth	4	0.1048	0.0262	1.28
Day x station x depth	12	0.4452	0.0371	1.82
Residual	40	0.8158	0.0204	

§ Based on logarithms of catch per liter.

† Probability: *$P<.05$; **$P<.01$; ***$P<.005$.

distribution of *Diaptomus* was like that of walleyes with respect to changes which occurred with wind velocity. Highest catches were at 2 meters on calm days and at 3 meters on windy days. The significant interaction for *Epischura* occurred only because of an unusually low catch at 2 meters on June 2.

Abundance of zooplankters at the various stations did not appear to be closely associated with water currents in the bay. Concentrations which might have been interpreted as due to currents on a given day did not occur on other days when current patterns were similar. The ephemeral nature of zooplankton distribution was illustrated by the day-night comparison on June 2.

Analysis of day-night catches revealed significant time of day by station interactions for catches of each zooplankter (Table 6). A change in horizontal distribution had taken place during the 7-hour interim between sampling periods. Inspection of the raw data showed that at night all zooplankters had decreased in abundance at Station 5, while increased catches occurred at Stations 2 and 3, except for *Diaptomus* which increased only at Station 1. The increased abundance of zooplankters near the western boundary of the bay suggested that they were being transported there by water currents which moved west on June 2 at depths of 2 meters and deeper.

A number of other significant sources of variation were present for the day-night zooplankton catches, including three significant second-order interactions. None of these was easily interpreted, but they emphasized the quick and complex changes which can occur in the distribution of zooplankton. Changes in yellow perch distribution between day and night resembled the western movement of zooplankton in the bay. Distributions of perch and zooplankton were not comparable over the four days, however, because that of zooplankton usually could not be explained by the water currents in the bay.

Relations Between Distribution of Organisms and Currents in the Bay

For catches of both walleye and yellow perch larvae, coefficients of correlation with catches of other organisms, with sample depth, with wind and with water current data were determined. Partial correlations were a better measure than simple correlations of the relation between larvae and each of the other variables, because the partials represented the relationship which existed between two variables independent of effects due to the other variables. In effect, a partial correlation coefficient represents the average correlation between two variables over all values of the remaining variables.

TABLE 6. FACTORIAL ANALYSIS OF VARIANCE§ FOR COMPARISON OF DAYTIME AND NIGHTTIME CATCHES OF FIVE GROUPS OF ZOOPLANKTON IN BILLINGTON BAY ON JUNE 2-3, 1967

Source of variation	Degrees of freedom	Sum of squares	Mean square	F†
Cyclops				
Time of day	1	0.0634	0.0634	9.98***
Station	4	1.0063	0.2516	39.61***
Time x station	4	0.1670	0.0417	6.57***
Depth	1	0.1584	0.1584	24.95***
Time x depth	1	0.3115	0.3115	49.05***
Station x depth	4	0.0546	0.0136	2.15
Time x station x depth	4	0.1093	0.0273	4.30**
Residual	20	0.1270	0.0064	
Diaptomus				
Time of day	1	0.0037	0.0037	0.41
Station	4	0.2663	0.0666	7.30***
Time x station	4	0.5431	0.1358	14.90***
Depth	1	0.2101	0.2101	23.05***
Time x depth	1	0.0103	0.0103	1.13
Station x depth	4	0.1760	0.0440	4.83**
Time x station x depth	4	0.0970	0.0242	2.66
Residual	20	0.1823	0.0091	
Epischura				
Time of day	1	0.3974	0.3974	23.79***
Station	4	2.0440	0.5110	30.58***
Time x station	4	1.9410	0.4852	29.04***
Depth	1	0.3182	0.3182	19.04***
Time x depth	1	0.0669	0.0669	4.00*
Station x depth	4	0.2392	0.0598	3.58**
Time x station x depth	4	0.2076	0.0519	3.10*
Residual	20	0.3342	0.0167	
Nauplii				
Time of day	1	0.0701	0.0701	1.92
Station	4	2.4626	0.6156	16.82***
Time x station	4	0.5920	0.1480	4.04**
Depth	1	0.0676	0.0676	1.85
Time x depth	1	0.0211	0.0211	0.58
Station x depth	4	0.1772	0.0443	1.21
Time x station x depth	4	0.5311	0.1328	3.63**
Residual	20	0.7320	0.0366	
Daphnia				
Time of day	1	0.0004	0.0004	0.02
Station	4	3.1650	0.7912	34.34***
Time x station	4	0.2975	0.0744	3.23*
Depth	1	0.0579	0.0579	2.51
Time x depth	1	0.00004	0.00004	0.002
Station x depth	4	0.1408	0.0352	1.53
Time x station x depth	4	0.2124	0.0531	2.30
Residual	20	0.4609	0.0230	

§ Based on logarithms of catch per liter.

† Probabiliay: $*P<.05$; $**P<.01$; $***P<.005$.

Because neither walleye nor yellow perch catches were homogeneous among the five sampling dates it was desirable to introduce a correction for day to day variability into calculation of the partial correlation coefficients for each species. This correction took the form of a sum of squares attributable to variation in catches among the five dates and was subtracted from the corrected total sum of squares in the partial correlation formula.

Logarithms of the catches of larval fish and zooplankton were used in the correlations. Wind directions were coded: 1 — east winds; 2 — west winds. Water current directions also were coded: 1 — east-moving currents; 2 — west-moving currents.

Simple correlation coefficients were calculated in addition to the partial correlations for comparison (Table 7), but only the partial correlations were considered in the interpretation of relationships. Correlations of walleyes and yellow perch with the organisms used as variables were not often significant. Walleye larvae were positively correlated with yellow perch larvae and copepod nauplii ($P < .001$). Yellow perch, besides being positively correlated with walleyes, also were positively correlated with burbot (*Lota lota*) larvae and *Cyclops* ($P < .001$), but they were negatively correlated with nauplii ($P < .001$). The high, positive partial correlation between walleye and yellow perch catches was significant, even though there was no simple correlation between the two species except during easterly winds.

Care must be taken in assigning cause and effect interpretations to correlations, but the positive, partial correlation between walleye and yellow perch larvae may indicate some attraction between the two species or a similar response to some environmental factor. Results of the correlations suggested that in the absence of wind and water-current effects, walleye and yellow perch larvae probably would be strongly associated in Billington Bay. Four of the five environmental factors had partial correlations which differed in sign for yellow perch and walleyes (Table 7). These differences could account for the dissimilarity in actual distribution of the two species despite the high, positive partial correlation between the two. The highly significant, positive partial correlation of walleye larvae with water-current direction ($P < .001$) showed that walleyes were most abundant in westward-moving currents. Yellow perch larvae were negatively correlated with water-current direction ($P < .001$) indicating that they were most often associated with currents moving east. The high positive correlation of yellow perch with burbot larvae and *Cyclops* may have been the result of a similar response by these organisms to wind and water currents.

TABLE 7. SIMPLE AND PARTIAL CORRELATION COEFFICIENTS BETWEEN CATCHES OF WALLEYE AND YELLOW PERCH LARVAE AND THE OCCURRENCE OF SIX OTHER ORGANISMS AND FIVE ENVIRONMENTAL FACTORS IN BILLINGTON BAY FOR FIVE DATES IN 1967

Variable	Walleye				Yellow perch			
	Simple		Partial		Simple		Partial	
	Value	Probability	Value	Probability	Value	Probability	Value	Probability
Walleye	..	..	..	..	+0.108	>.20	+0.770	<.001
Yellow Perch	+0.108	>.20	+0.501	<.001	..	..	..	..
Burbot	−0.094	>.20	−0.143	>.05	+0.357	<.001	+0.689	<.001
Epischura	−0.017	>.50	+0.146	>.05	+0.171	<.05	−0.006	>.50
Diaptomus	+0.150	>.10	−0.028	>.25	+0.027	>.50	+0.134	>.10
Cyclops	+0.151	>.10	−0.163	>.05	+0.234	.01	+0.613	<.001
Nauplii	+0.244	<.01	+0.256	<.001	−0.079	.40	−0.659	<.001
Daphnia	−0.233	.01	−0.037	>.25	+0.022	>.50	−0.057	>.25
Wind velocity	−0.219	.025	−0.578	<.001	+0.362	<.001	+0.728	<.001
Wind direction	−0.054	>.50	+0.289	<.001	+0.202	.025	−0.145	>.05
Water velocity	−0.012	>.50	+0.269	<.001	+0.108	>.20	−0.110	>.10
Water direction	+0.408	<.001	+0.627	<.001	−0.179	.05	−0.674	<.001
Sample depth	+0.128	<.10	+0.085	>.10	−0.020	>.50	+0.005	>.50

DISCUSSION

Distribution of yellow perch and walleye larvae in bays along the south shore of Oneida Lake is due to a complex interaction of hydrographic features and larval behavior. Many of the factors causing the observed distributional differences between the two species remain unexplained, but a series of four related factors are important in producing the distribution patterns observed in Billington Bay. The origin of walleye larvae from a hatchery source along the northwest shore of the lake was an additional factor, because larvae stocked at that location drift southeast and are transported to the vicinity of the bays (Houde and Forney, in press).

The first of the four factors causing walleye larvae to be concentrated in Billington Bay was the presence of an eddy from 2 meters below the surface to near the bottom during westerly winds. Larvae which were carried to the bay might be retained there by the eddying pattern of currents, as has been described for marine fish larvae (Fraser, 1958; Saville, 1965). An eddy, like the one observed in Billington Bay, also was present in an adjacent bay and probably is a common feature of south shore bays in Oneida Lake. A second factor contributing to the observed distribution was the avoidance of surface water by walleyes, but not by yellow perch, on windy days. This difference in behavior caused yellow perch, which remained near the surface, to be transported in a direction similar to that of the wind, while walleyes were retained in the eddy. Retention of winter flounder (*Pseudopleuronectes americanus*) larvae by currents in an estuary also has been found to depend on depth selection by the larvae (Pearcy, 1962). The third factor affecting the distribution of walleye and yellow perch larvae in the bay was the difference between current velocities near Stations 1 and 2 compared with those at the other stations. Currents at depths of 2 and 3 meters averaged less near Stations 1 and 2, apparently causing walleye larvae in the eddy to be concentrated along the western perimeter of the bay. A fourth factor was the swimming ability of walleye larvae, which must have been developed enough to resist transport out of the area. Concentration of walleye larvae in the bay began at about 9 millimeters in total length, when they had an ability to sustain themselves against currents of 2.5 centimeters per second (Houde, 1969). Currents measured at depths of 2 and 3 meters on the four sampling dates ranged from 0.5 to 5.0 centimeters per second near Stations 1 and 2, but from 4.0 to 7.0 centimeters per second near the remaining stations. Average velocities near Stations 1 and 2 approximated current velocities at which walleyes could swim for sustained periods, but velocities at the other stations exceeded this

level. Yellow perch larvae of 8.5 millimeters in total length also could sustain themselves against 2.5-centimeters-per-second currents, but their usual concentration near the surface placed them in currents stronger than any they might sustain.

Associations between larvae and zooplankton remained obscure; only copepod nauplii exhibited a significant positive partial correlation with walleye larvae. Because walleyes were consistently concentrated in the western third of the bay, it was not surprising that few correlations were found. Yellow perch larvae were positively correlated with *Cyclops* but negatively correlated with nauplii. In addition, a high positive correlation of perch larvae and burbot larvae was observed. Distribution of zooplankters changed rapidly from day to day, as did that of yellow perch, increasing the likelihood of significant correlations between the two. Simple correlation coefficients had been calculated for the catches on each date, though not presented in this paper. Signs of the simple correlation coefficients between the two species of larvae and the other organisms changed from day to day, reflecting the instability of any associations which might exist.

An interesting result of the partial correlation analysis was the strong, positive association between catches of walleyes and yellow perch in Billington Bay. Some evidence is available to indicate that the positive partial correlation of the two species was not fortuitous, but, in fact, expressed a real relationship. Partial correlations between the two species were positive and highly significant for data pooled from the five series of samples. Because the effect of the other variables on the perch-walleye association was eliminated in calculating the partial correlation, there is reason to believe that a positive association would be consistently observed in the absence of certain environmental influences. Walleyes become predators of yellow perch early in the postlarval stage (Houde, 1967), and this relationship may be reflected in the partial correlations. If walleye larvae associate and swim with schools of yellow perch larvae, as Eschmeyer (1950) believed possible, this might account for the positive correlation which was noted. The most probable source of the correlation, however, is that both species were highly correlated with some environmental factor not included in the analysis. If some feature of the environment was either highly repellent or attractive to both walleye and yellow perch larvae, the two species would be positively correlated, but not through any mutual attraction.

Walleye larvae were abundant in other bays along the south shore of Oneida Lake in addition to Billington Bay (Forney and Houde, 1964; Houde and Forney, in press). Larvae in the bays are still truly

limnetic since they are not found near shore in 1 to 2 meters of water. The relative abundance of larval walleyes in the bays, compared with that in the open lake, may have adaptive significance for the species although the survival value of this particular type of distribution is unknown. Zooplankton sampling failed to demonstrate that preferred food organisms were most abundant where walleyes were concentrated. However, turbulence was less along the western boundaries of the bays during predominantly west winds. Even though food was not more abundant in these areas, feeding conditions may have been better in the relatively calm water and low-velocity currents. Walleye larvae first appeared in Billington Bay at about 9 millimeters in total length when their yolk reserves were nearly exhausted and an exogenous food source was necessary. If it is advantageous for walleye larvae to be concentrated in bays, a similar advantage might be expected for perch larvae but no such concentrations have been observed. However, yellow perch larvae are relatively more abundant than walleye larvae in all areas of Oneida Lake, and any advantage obtained from a stable distribution pattern toward establishing a successful year class might not be as important to perch as to the less abundant walleye. In fact, because perch larvae are so abundant in Oneida Lake, concentrations in bays might be detrimental to this species, since crowding and competition for a limited food supply likely would occur.

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MOVEMENT OF TAGGED BLACK BEARS IN THE ADIRONDACKS[1]

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ABSTRACT

A total of 161 black bears from the Adirondack region were trapped and ear tagged from 1956 through 1965, and 208 recoveries were recorded by retrapping and hunting. Animals released within 5 miles of the trapsite dispersed randomly, males moving a mean distance of 8.6 miles, and females a mean distance of 7.4 miles. Recoveries during the summer were confined mainly to areas where tourist and camping facilities provided a supplementary food supply. Dispersal from these areas was noted during October and November. A better definition of home range is needed than that provided by recovery data of this sort, i.e., one that relates the size and shape of home range to the animals' yearly activities.

Nuisance animals transferred between 8.7 and 66.6 miles from the trapsite tended to move back in the direction from which they were transferred, and 22 of 52 such bears returned home. Homing fell off sharply when animals were transferred more than 40 miles; however, one male returned home after being transferred 56 miles. This success in homing indicates a homing instinct and/or familiarity of many bears with much of the Adirondack range. Thus, transfer is not a practical solution to the nuisance bear problem in the Adirondacks.

The objectives of this study were to determine the size of the home range of the black bear *(Ursus americanus)* in the Adirondack region, to measure movement in relation to food abundance and other influences and to observe the homing behavior of transferred animals. A knowledge of the size of the home range and influences on movement is of value in population studies and in setting proper hunting seasons. Information on homing behavior is needed to determine whether trap-and-transfer programs can be an effective control of nuisance bears.

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Burt (1943) defined the home range of mammals as that area traversed by the individual in its normal activities of food gathering, mating and caring for young. Published estimates of the size of a black bear's home range fail to relate to these basic activities. Seton (1929) states that "the individual bear is a wide ranger. Mitigwab, Indian guide of Mattawa, tells me that he several times followed a big bear on a round of 15 miles from its home." Leopold (1936) gave the yearly cruising radius of black bears as only 5 miles. Cahalane (1947) stated that "Once the bears leave their den, they do not return to it, at least before autumn. Within a range of perhaps ten miles in radius they are nomads for the next half year. The solitary male has a home range of about fifteen miles." Spencer (1955) believed the average range of bears in Maine to be about 5 miles in radius. Jackson (1961) believed that males normally range 10 or more miles, females with cubs 4 or 5 miles, and stated "There is some evidence of old bears wandering distances up to 80 miles or possibly more from their established range."

More recent studies have involved trapping and ear tagging in attempts to determine the home range of black bears. Knudsen (1961) in Wisconsin found that average movement by ear-tagged males was 15½ miles with a maximum of 46 miles in 2 months. The average movement by 15 ear-tagged females was less than 2 miles, while two other females moved 16 and 36 miles. Erickson *et al.* (1964) in a tagging study on the upper peninsula in Michigan found that 25 bears not transplanted moved a mean distance of 4.6 miles after an average time lapse of 195 days (range 7 to 787 days). On the other hand, 17 transplanted bears were recovered mean distances of 22.1 miles from the point of release and 34.1 miles from the point of original capture after an average time lapse of 104 days (range 6 to 391 days). Only three transplanted animals were recovered near their original capture sites. One adult male transplanted 96 miles was recovered 35 days later within 6 miles of its capture site, and one adult female, separated from its cubs and moved 64 miles, was recovered 120 days later 19 miles from its original capture site.

The limitations on determining home range from recovery data were pointed out by Hayne (1949), Davis (1953) and Stickel (1954). However, this is the only feasible approach presently available for estimating black bear range in New York.

METHODS

From 1956 to 1958 an intensive live-trapping and ear-tagging program for black bears was contracted to Cornell University. From

the fall of 1958 through the 1965 big game season, the program was continued for cubs and nuisance animals by the Conservation Department's big game research project and regional personnel.

Live-trapping and handling procedures were described by Black (1958) and Black *et al.* (1959). Bears were individually marked with ear tags in the manner found to be successful by Erickson (1957) in Michigan. Monel metal, self-piercing ear tags manufactured by the National Band and Tag Company (Newport, Kentucky) were used to tag each bear in both ears. Both cattle tags (size No. 19) and sheep tags (size No. 18) were used. In addition to ear tags, the use of reflector tags was begun in 1961 and of plastic ear streamers in 1963 to facilitate sight identification. Also in 1963, tatooing on the upper lip and groin was begun for permanent identification in case both ear tags were lost.

This paper pertains to movements of bears trapped and released in the Adirondack region only. Trapsites were not selected in a random grid pattern. Efforts were concentrated on handling bears from dumps near towns or campsites. A few animals were trapped at wild sites. The majority of bears trapped at dumps were released within 5 miles of the trapsite, presuming that this did not transfer them from their home range. A few bears trapped at dumps and all nuisance bears trapped at campsites, homes and restaurants were transferred more than 5 miles from the trapsite to determine whether this was a feasible solution to the nuisance problem. All releases were made during the months of June through September. Bears trapped at wild sites were not transferred.

Information on movement was obtained by retrapping (June to October) and from hunter returns (October to December). Some sight records of ear-tagged bears by reliable individuals were also used. No information on this subject was obtained from January through May. Summer recoveries could not be considered random because most traps were located at dumps. Since bears disperse from the dumps during the fall, hunter returns were considered random. A $25 reward was offered for the return of the ear tags and skull and the kill location of all ear-tagged bears.

Distance and compass direction of movement between release and recovery points were determined from U. S. Geological Survey topographic maps on which the points were plotted. Distance and direction from the previous capture point were determined in the same way. Movements were analyzed by sex according to whether the animals had been released within 5 miles of the trapsite or transferred a greater distance. The relationship between movement and age of the animals could not be analyzed because ages assigned

by the tooth-sectioning technique (Sauer *et al.*, 1966) were available for too few bears.

FINDINGS

Ear tags were retained satisfactorily. Over a period of two years, in 144 recoveries of 124 bears, single tags were lost in 17 cases, and both tags in only five cases. All tag losses involved adult males, and those that had lost both tags could be identified by the absence of one testicle which was removed during the original processing. The 20 adult females and seven cubs recovered during this period retained both ear tags. The loss of cattle tags was one-third that of the smaller sheep tags.

A total of 161 bears were trapped from 1956 through 1965 and were involved in 208 recoveries. Of these bears, 147 were originally trapped at dumps or as nuisance animals, only 14 at wild trapsites. Five of the 14 bears originally trapped at wild sites were retrapped at dumps, and eight originally trapped at dumps were retrapped at wild sites, so no attempt was made to distinguish wild bears from dump bears.

Bears Released Within 5 Miles of Trapsite

Bears that were released within 5 miles of the trapsite were considered not to have been transferred. There were 152 recoveries of such bears, 46 of which occurred at the original trapsite. The latter were disregarded in analyzing movement. For the remaining 106 recoveries, the distance and direction the bears moved, in relation to an assumed common release point, are plotted in Figure 1. They were distributed, by quadrant, as follows: 0° to 89°, 26 males and 8 females; 90° to 179°, 14 males and 4 females; 180° to 269°, 24 males and 7 females; 270° to 359°, 18 males and 5 females. A chi-square comparison showed no significant difference between this and a random distribution with 26.5 recoveries in each quadrant. Since direction of movement appeared to be random, further analysis was concerned with sex and distance traveled.

A total of 91 male bears were released within 5 miles of the trapsite. Of the 116 recoveries, 34 occurred at the original trapsites which were all dumps. For the remaining 82 recoveries, movements ranged from 0.2 to 37.5 miles with a mean of 8.6 ± 0.9. Because of the large standard error, the records were analyzed by the time elapsed between release and recovery, and also by month of recovery, in an attempt to determine more representative means. The data with respect to elasped time are summarized in Table 1 and show that the distance moved tended to increase as the interval between

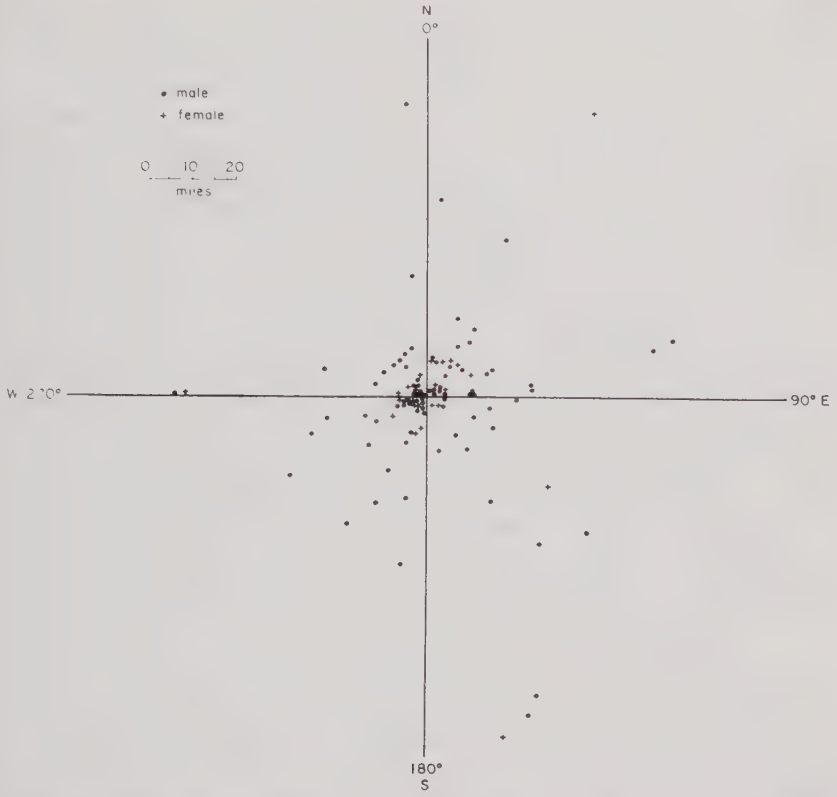

Figure 1. Distance and direction of recovery points, in relation to an assumed common release point, for bears released within 5 miles of trapsite.

release and recovery increased. The data are summarized in Table 2 according to the month in which the recoveries occurred. The recoveries for a given month may have represented a range of from a few weeks to several years in the period that had elapsed after the bear had been released. For animals recovered during the months of June through October, the mean movement was quite uniform. All recoveries at original dump sites occurred during these months. However, it was substantially greater for those recovered in November. In all cases, the means were averages of both very short and very long distances, so standard errors remained large. Only the November records provided enough data to analyze the distance according to the yearly periods involved. For these records: for nine males recovered during the year trapped the mean was 11.2 miles; for five recovered the following year it was 15.0 miles; and for seven recovered in subsequent years it was 23.1 miles.

TABLE 1. MOVEMENT OF MALE BLACK BEARS IN RELATION TO ELAPSED TIME FOR ANIMALS RELEASED WITHIN 5 MILES OF TRAPSITE*

Recovery period	Number	Elapsed time (days)		Movement (miles)			
		Mean	Range	Mean	Standard error	Median	Range
Same year	34	55	2- 117	6.5	1.3	5.0	0.4-32.8
Following year	25	402	280- 491	7.8	1.5	5.3	0.8-27.8
Subsequent years	23	1,345	685-2,252	12.5	2.3	8.4	0.2-37.5
Total	82	523	2-2,252	8.6	0.9	5.6	0.2-37.5

* Recoveries at original trapsite (21 during same year, 11 during following year and 2 in subsequent years) not included.

TABLE 2. MOVEMENT OF MALE BLACK BEARS IN RELATION TO MONTH OF RECOVERY FOR ANIMALS RELEASED WITHIN 5 MILES OF TRAPSITE*

Month of recovery	Number	Movement (miles)			
		Mean	Standard error	Median	Range
June	8	7.5	2.2	6.2	1.0-17.2
July	12	5.0	0.6	5.2	1.0- 8.4
August	13	6.5	1.8	4.0	0.8-22.0
September	4	6.7	§	8.2	0.2-10.0
October	23	5.8	1.2	4.4	0.4-23.5
November	21	16.6	2.5	12.9	2.0-37.5
December	1	3.5	..	..	..
Total	82	8.6	0.9	5.6	0.2-37.5

* Recoveries at original trapsite (8 during June, 12 during July, 11 during August, 2 during September and 1 during October) not included.

§ Insufficient data to be meaningful.

Data on movement of females were limited because most female bears were autopsied when originally captured for examination of their reproductive tracts. A total of 25 females were released within 5 miles of the trapsite. Of the 36 recoveries, 12 occurred at the original trapsites, and five of the latter involved the same animal. For the remaining 24 recoveries, movements ranged from 0.4 to 39.1 miles with a mean of 7.4±2.2. Distance in relation to elapsed time (Table 3) showed no pattern. The data are summarized in Table 4 according to the month in which the recoveries occurred and represent the same possible ranges of time as for the males. For the five recoveries during the summer (June-September) the mean was

TABLE 3. MOVEMENT OF FEMALE BLACK BEARS IN RELATION TO ELAPSED TIME FOR ANIMALS RELEASED WITHIN 5 MILES OF TRAPSITE*

Recovery period	Number	Elapsed time (days)		Movement (miles)			
		Mean	Range	Mean	Standard error	Median	Range
Same year	6	71	12- 119	5.4	2.3	4.0	0.4-16.6
Following year	7	427	320- 502	8.4	5.6	3.2	1.4-39.1
Subsequent years	11	1,389§	790-2,347	7.8	3.6	2.3	0.6-36.5
Total	24	779	12-2,347	7.4	2.2	3.6	0.4-39.1

* Recoveries at original trapsite (6 during same year and 6 during following year) not included.

§ For two bears, for which only the month of recovery was known, the average day of recovery for others recorded during the same month was used.

TABLE 4. MOVEMENT OF FEMALE BLACK BEARS IN RELATION TO MONTH OF RECOVERY FOR ANIMALS RELEASED WITHIN 5 MILES OF TRAPSITE*

Month of recovery	Number	Movement (miles)			
		Mean	Standard error	Median	Range
June	2	2.0	§	2.0	1.4- 2.5
July	1	5.1	..	..	..
August	1	4.5	..	..	..
September	1	1.5	..	..	..
October	10	9.8	4.2	2.8	1.2-39.1
November	9	7.1	3.7	4.3	0.4-36.5
Total	24	7.4	2.2	3.6	0.4-39.1

* Recoveries at original trapsite (1 in June, 8 in July and 3 in August) not included.

§ Insufficient data to be meaningful.

3.0±0.8 miles. All recoveries at the original trapsite occurred from June through August.

Movements of bears released within 5 miles of the trapsite are shown, in relation to the extent of the primary bear range in the Adirondacks (Figure 2), for summer recoveries in Figure 3, for October recoveries in Figure 4 and for November recoveries in Figure 5. Summer recoveries were confined mainly to the area where tourist and camping facilities provided a supplementary food supply. However, traps were not set outside this area and hunting was illegal during this season, so any activity elsewhere would not have been

Figure 2. Map of northern New York showing extent of primary bear range in the Adirondacks.

noted. Dispersal from this area was noted for two males and two females in October and for 10 males in November. A *t*-test showed no significant difference between the mean movement of males and that of females during the summer and during October, but for November the difference was significant at the 5 per cent level of confidence.

Bears Transferred 5 Miles or More From Trapsite

To determine homing tendency, 42 male bears and 10 females were transferred from 8.7 to 66.6 miles from original trapsite. Three males and one female were transferred a second time. All these animals were trapped at dumps or as nuisance animals. As a criterion of homing tendency, an estimate of home range size was necessary, and the mean distance moved by bears released within 5 miles of the trapsite was chosen as the radius of an assumed circular home range. Thus, male bears that returned to within 8.6 miles

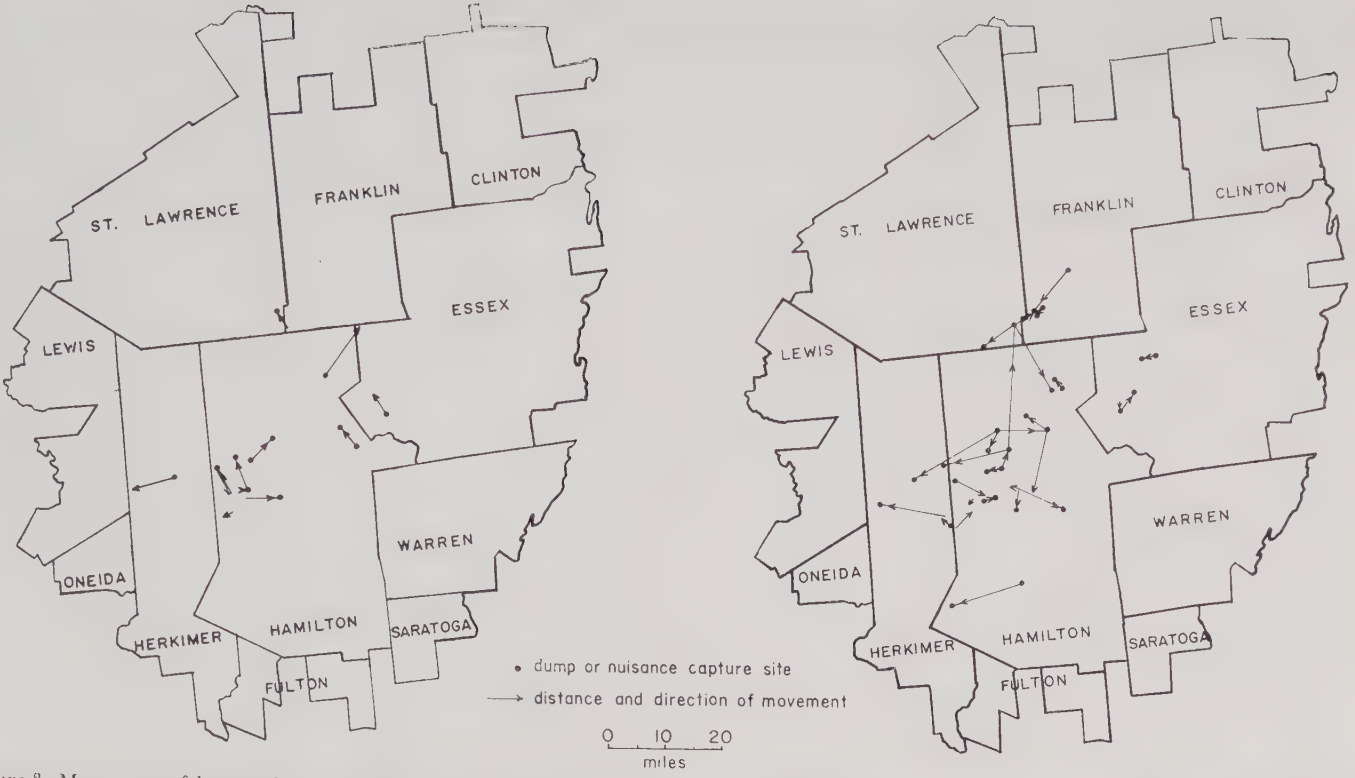

Figure 3. Movement of bears released within 5 miles of trapsite and recovered during the summer (June to September): (left) of the same year; (right) of subsequent years. Two others in same year recovered too close to release site to be shown.

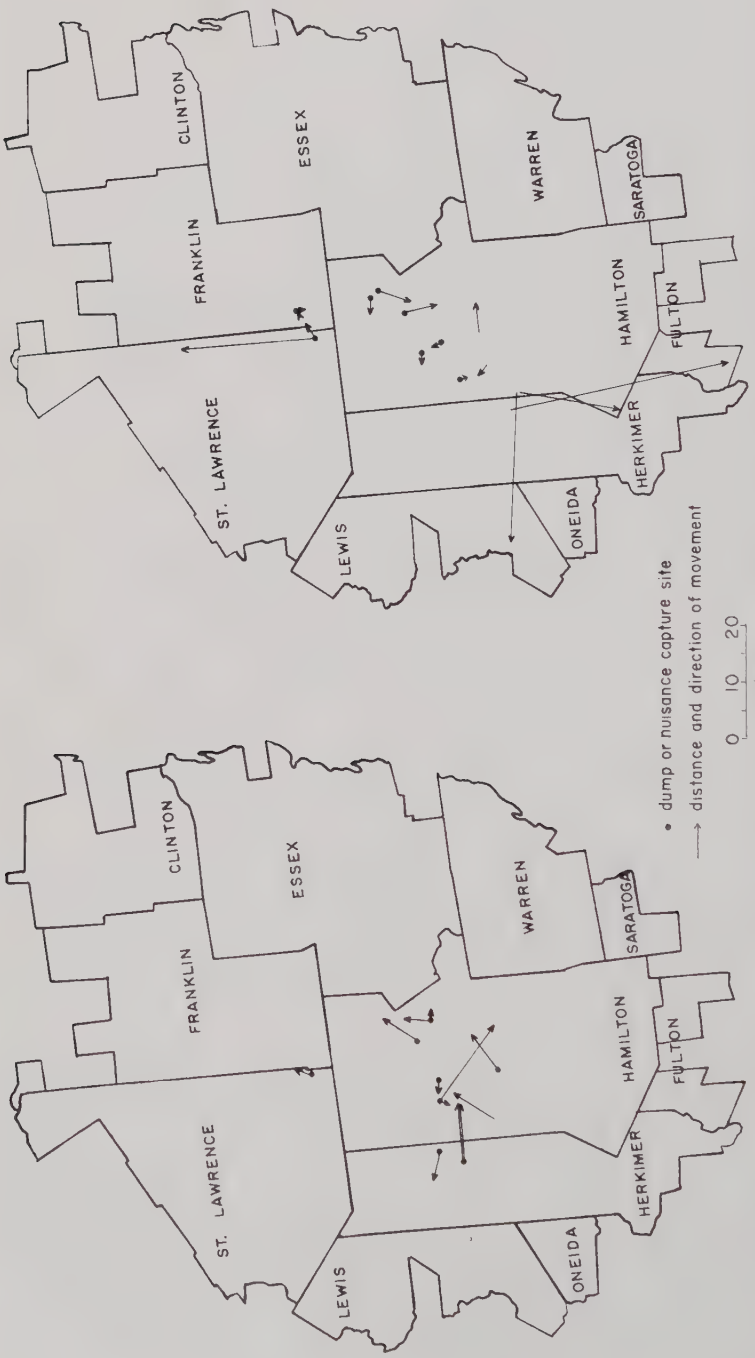

Figure 4. Movement of bears released within 5 miles of trapsite and recovered during October: (left) of the same year; (right) of subsequent years. Five others in the same year and one in subsequent years recovered too close to release site to be shown.

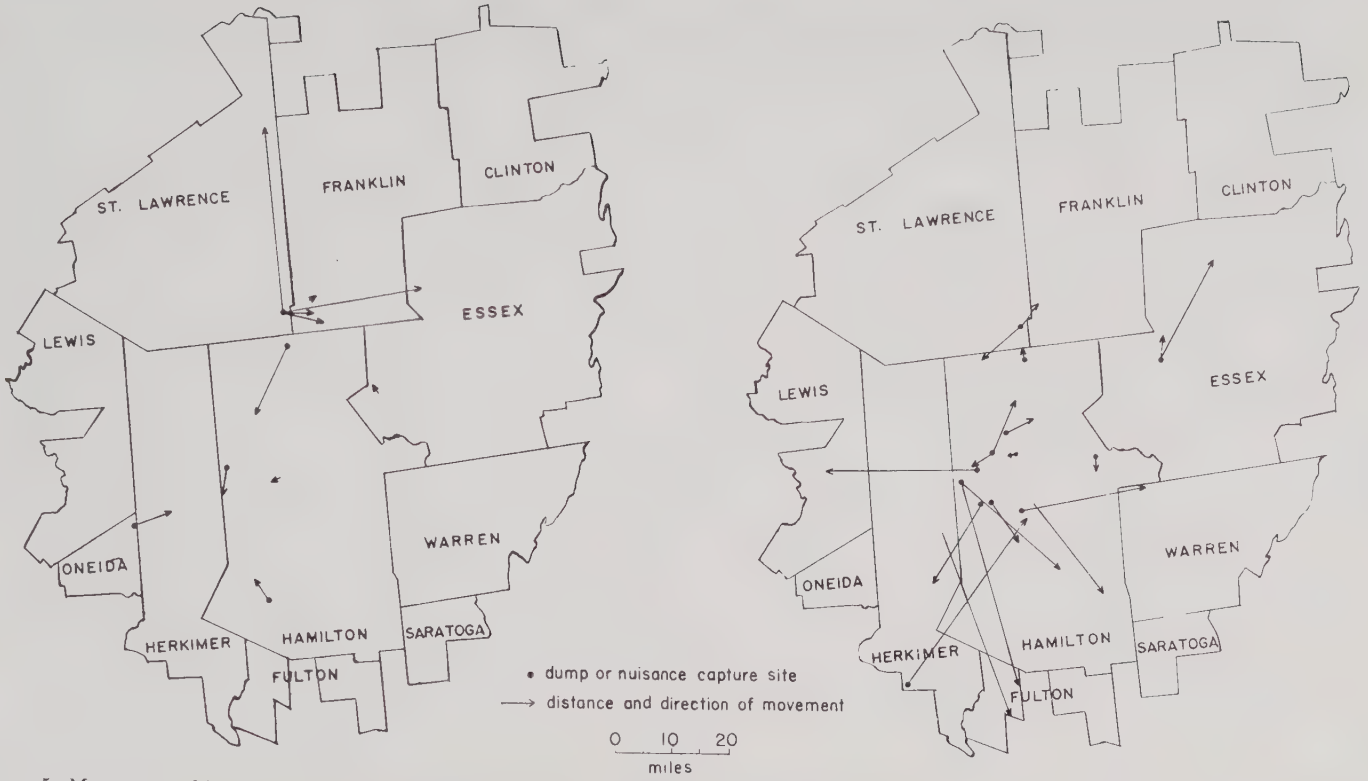

Figure 5. Movement of bears released within 5 miles of trapsite and recovered during November: (left) of the same year; (right) of subsequent years.

of the original trapsite, and female bears that returned to within 7.4 miles, were considered to have returned "home".

There was a marked tendency for the transferred bears to move back in the direction from which they were transferred. The distance and direction of transfer and of subsequent recovery for each bear are presented in Figures 6 through 9 according to the quadrant (with respect to the trapsite) to which it was transferred. In each figure the data are plotted as though all bears were captured at a common site and released at a common site. Therefore, the intersection of the coordinate lines represents the trapsite in relation to the solid lines, and the same intersection represents the release point in relation to the dashed lines. Of the 27 bears that were transferred into the 0° to 89° quadrant, 21 were recovered in the opposite quadrant (Figure 7); of the 11 transferred into the 90° to 179° quadrant, six were recovered in the opposite quadrant (Figure 9); of the 16 transferred into the 180° to 269° quadrant, eight were recovered in the opposite quadrant (Figure 8); and both bears transferred into the 270° to 359° quadrant were recovered in the opposite quadrant (Figure 6). Of the 56 bears transferred, 37 (66 per cent) returned toward their home quadrant. However, the number of bears that returned "home" was closely related to the distance they had been transferred (Table 5) and homing behavior is discussed in relation to the distance they were transferred.

Bears Transferred 8.7 to 19.9 Miles Of the 13 males and three females in this group, six males and two females returned home. The eight bears that did not return were recovered at an average distance of 14.6 miles from the original capture site and 15.2 miles from the release site. Judging from distance and direction of travel, three males passed through their home range and traveled beyond, and two of them were killed as nuisance animals.

Bears Transferred 20.0 to 29.9 Miles Of the eight males and two females in this group, two males and one female returned home. The remaining seven bears were recovered at an average distance of 19.5 miles from the original capture site and 14.7 miles from the release site. Two males had moved in a direction that eventually would have intersected their home range, and these two plus a third male were recovered at dumps. One female had presumably passed through its home range and traveled beyond.

Bears Transferred 30.0 to 39.9 Miles Of the 13 males and three females in this group, six males and two females returned home. The remaining eight bears were recovered at an average distance of 19.2 miles from the original capture point and 25.1 miles from release point. Three males had moved in a direction that would have intersected

TABLE 5. COMPARATIVE DATA FOR TRANSFERRED BLACK BEARS THAT RETURNED TO THEIR HOME RANGE AND THOSE THAT DID NOT ACCORDING TO THE DISTANCE THEY WERE TRANSFERRED

Group*	Number of bears			Percentage returned	Recoveries			
					Mean distance (in miles) from		Mean elapsed time (in days)	
	Male	Female	Total		Trapsite	Release point	Male	Female
Transferred 8.7 to 19.9 miles								
Returned	6	2	8	50.0	xxx	..	289	638
Did not return	7	1	8	xxx	14.6	15.2	368§	793
Transferred 20.0 to 29.9 miles								
Returned	2	1	3	30.0	xxx	..	8	444
Did not return	6	1	7	xxx	19.5	14.7	230	1,217
Transferred 30.0 to 39.9 miles								
Returned	6	2	8	50.0	xxx	..	416	622
Did not return	7	1	8	xxx	19.2	25.1	299	61
Transferred 40.0 to 49.9 miles								
Returned	2	0	2	25.0	xxx	..	226	..
Did not return	4	2	6	xxx	51.7	10.3	371	987
Transferred 50.0 to 59.9 miles								
Returned	1	0	1	25.0	xxx	..	400	..
Did not return	2	1	3	xxx	50.0	13.8	486	2,599
Transferred 60.0 to 69.9 miles								
Returned	0	0	0	0.0	xxx	..	..	..
Did not return	2	0	2	xxx	76.3	32.2	295	..

* "Returned" represents recoveries within 8.6 miles of original trapsite for males, within 7.4 miles for females; "did not return" represents recoveries at greater distances.

§ For one male, for which only the month of recovery was known, the average day of recovery for others recorded during the same month was used.

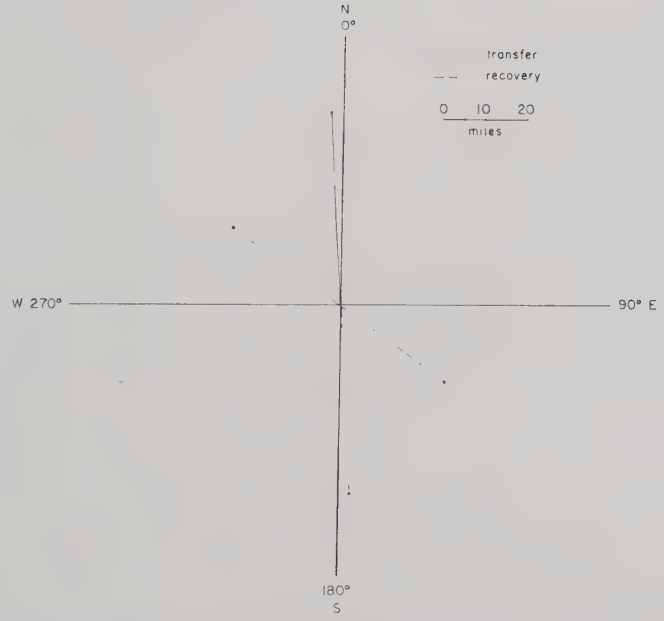

Figure 6. Distance and direction of transfer and recovery for bears released in northwest (270° - 359°) quadrant 5 miles or more from trapsite. (see text for explanation of focus)

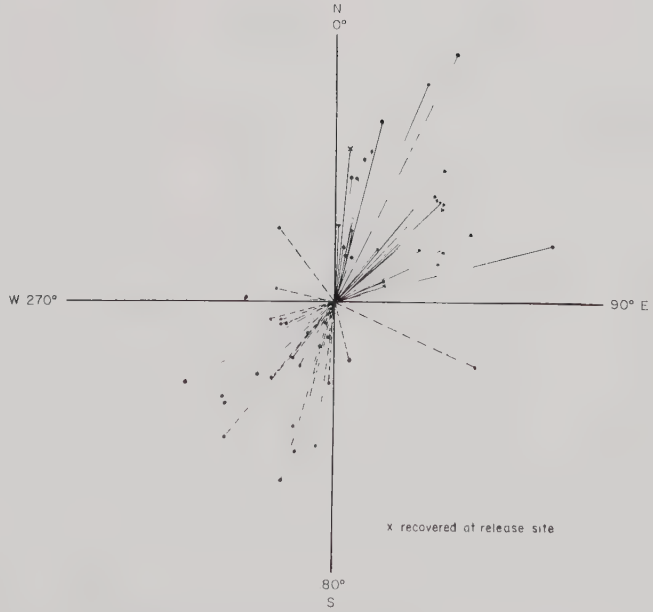

Figure 7. Distance and direction of transfer and recovery for bears released in northeast (0°-89°) quadrant 5 miles or more from trapsite. (see text for explanation of focus)

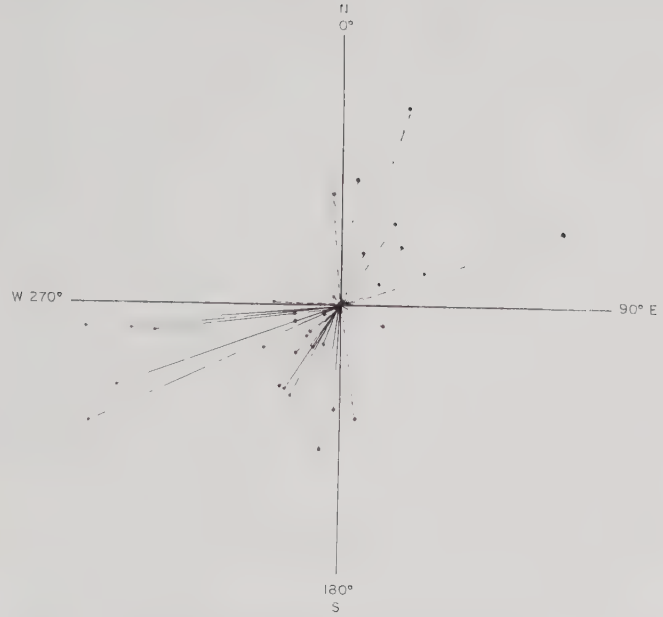

Figure 8. Distance and direction of transfer and recovery for bears released in southwest (180° - 269°) quadrant 5 miles or more from trapsite. (see text for explanation of focus)

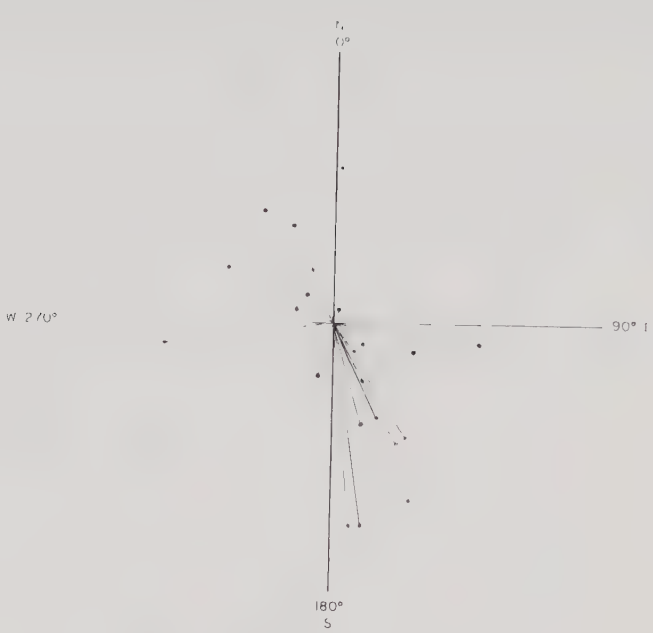

Figure 9. Distance and direction of transfer and recovery for bears released in southeast (90° - 179°) quadrant 5 miles or more from trapsite. (see text for explanation of focus)

their home range. These three plus a fourth male were recovered at dumps or as nuisance animals. A fifth male had presumably passed through its home range and traveled beyond.

Bears Transferred 40.0 to 49.9 Miles Of the six males and two females in this group, only two males returned home. The remaining six bears were recovered at an average distance of 51.7 miles from the original capture point and only 10.3 miles from the release point.

Bears Transferred 50.0 to 59.9 Miles Of the three males and one female in this group, one male returned home. The remaining three bears were recovered at an average distance of 50.0 miles from the original capture site and 13.8 miles from the release site. The female was killed as a nuisance animal.

Bears Transferred 60.0 to 69.9 Miles The two males in this group apparently became completely disoriented. They were recovered at distances of 74.0 and 78.6 miles from capture site, one being shot in the city of Rome (N. Y.) 27 miles south of the release point.

Degree of Homing The longest distance from which a bear returned to its home range was 56 miles in the case of a male that had been transferred to the Tug Hill plateau, an area completely discontiguous from the Adirondack Mountains. Four other males transferred to Tug Hill did not return home, including the one shot in Rome. Of the 56 recoveries of transferred bears, 22 represented animals taken at dumps or as nuisance individuals.

Distance transferred had little relation to the length of time between release and recovery. Males were recovered within their home range in 2 days after being transferred 10.2 miles; in 8 days after being transferred 12.4, 23.5 and 24.5 miles; and in 11 days after being transferred 34.4 miles. The data are summarized in Table 5. Mean recovery intervals were similar for males that returned home and those that did not. The mean interval for all transferred males was 315 days. This was considerably less than that of 523 days for males released within 5 miles of the trapsite (Table 1) and raises the question of whether transferring makes the animals more vulnerable. Only 40 per cent of the transferred males were recovered by hunters, compared with 54 per cent for the non-transferred males. The recovery intervals for transferred males taken by hunting and by retrapping were virtually indentical, and both were shorter than in the case of non-transferred males. The mean recovery interval for the transferred females was 873 days, compared with that of 779 days for females released within 5 miles of the trapsite (Table 3). The mean interval for transferred animals, however, is not an accurate measure of how quickly these animals returned to their home

range, since they may have actually returned weeks or months before being recovered.

DISCUSSION

The mean distances moved, as given in Tables 1 and 3, cannot be considered an adequate definition of the home range of the black bear. Of 114 animals not transferred (two originally not transferred were transferred on second capture), 85 were recovered only once. The only information available for these bears was the point of capture, the point of recovery and a period of time. To consider the distance between the capture point and recovery point to represent the radius of the bear's home range is presumptive. Periods of time between capture and recovery were so great that they gave no indication of the relationship of the capture point and recovery point to the animals' activities.

The indication that females range more widely during October and November, and males more widely during November, than they do during the summer seems basically sound. By November, lack of food at dumps, hunting pressure, availability of wild foods (beechnuts, acorns, etc.) and denning are all factors which contribute to dispersal of bears. However, size and shape of the fall range cannot be determined from this study, and neither can the relationship between summer and fall ranges.

That the distance moved for males increased as the time interval between release and recovery increased does not necessarily indicate that the size of the home range increases with time. It may well mean that one or two seasons are not an adequate length of time to define the size of the home range accurately. It may also mean that a bear's home range is not static but may change from time to time. Female bears usually breed every two years, and the breeding season and raising of cubs would certainly influence the animal's activities. Also, dispersal in relation to age needs to be determined.

The size of the home range can also be approached from the amount of bear range available in the Adirondacks for the population which exists. The range in this region has been estimated at 9,283 square miles (Sauer and McCaffrey, 1965). The minimum population of adult bears which could sustain the calculated annual harvests would be about 1,000. This would allow only 9¼ square miles of non-overlapping range for each adult. Since the average movement recorded was 8.6 miles for males and 7.4 miles for females, and the actual population is probably greater than 1,000, the bears must have overlapping home ranges. Craighead and Craighead (1966) found that grizzlies in Yellowstone National Park have overlapping

home ranges with a dominant male and an established "peck order". Possibly a similar arrangement prevails among black bears.

Since the direction of movement of the transferred bears tended to be in the direction opposite from transfer, it can be assumed that bears exhibit a homing tendency and/or that many of these bears actually were not tansferred from territory with which they were familiar. Since bears released within 5 miles of the trapsite dispersed as far as 39.1 miles in the fall and since the degree of return dropped off sharply for bears transferred more than 40 miles, it would appear that the latter hypothesis is the more probable and that many bears are familiar with large parts of the Adirondack range.

Transferring bears from 40 to 60 miles to alleviate nuisance problems does not seem practical on a large scale. In many cases the nuisance is simply relocated. As long as dumps are available, bears will be attracted to them. Public education on proper refuse disposal or higher bear harvests would be more effective remedies for nuisance problems.

Since tagging and recovery data have not provided the basic information needed for determining the size of the home range of the black bear, new approaches to the problem are needed. Recent research on radio tracking of animals has been encouraging. Craighead and Craighead (1965) have successfully monitored grizzly activity with radio equipment. Sanderson (1966) suggested that, to be meaningful, knowledge of the size and shape of the home range should be related to the ecology of a species. These should be considered in planning furure research.

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AGE AT MATURITY OF SCUP FROM NEW YORK WATERS[1]

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ABSTRACT

Ovaries and testes were examined from 849 male and 440 female scup collected from the Peconic Bays of eastern Long Island between June 1, 1964 and September 14, 1966. Based upon gross examination of the gonads for males and observations of the morphological characteristics of the eggs and the ovary weight-body weight relationship for females, it was determined that some scup were sexually mature at 2 years of age. The data also confirm that scup spawn in these waters between early May and mid-July. Age-frequency distributions for males and females are presently separated.

The scup *(Stenotomus chrysops)* is one of the most valuable marine fin fish resources of New York. During the period 1956 through 1962, over 10 million pounds valued at between $700,000 and $900,000 to the fisherman were landed in the State each year by the commercial fishery. In spite of its importance, past observations on the biology of the scup in New York waters are almost totally lacking. To establish a base of biological information for use in formulating sound management of the resource, life history studies (i.e., age and growth, age at maturity, and rate of exploitation and migration) on the species were conducted in the Peconic Bays of eastern Long Island between May 1964 and October 1966. The present report deals with age at maturity. Observations on age and growth were previously reported (Finkelstein, 1969).

Although moderate amounts of information about spawning are recorded in the works of Goode (1884), Bean (1903), Kuntz and Radcliff (1917), Nichols and Breder (1926), Perlmutter (1939), Breder (1948), Merriman and Sclar (1952), Bigelow and Schroeder (1953), Wheatland (1956), Marak and Colton (1961), Anonymous (1962), Marak *et al.* (1962) and Herman (1963), there is a paucity of data concerning the age at maturity of scup. Of the foregoing accounts, only three contain statements pertaining to the age of sexual maturity. Goode (1884), for example, quoting Professor Baird, maintained that "The female fish of the second year not unfrequently contains mature eggs". Nichols and Breder (1926) also reported that "Spawning probably takes place for the first time in the third summer", and this was further reiterated by Breder (1948). None of the latter authors described the method by which the ages of fish asserted to be sexually mature were determined.

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[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

METHODS AND MATERIALS

During the periods of June 1 through October 8 in 1964, May 7 through September 13 in 1965 and May 11 through September 14 in 1966, scup were collected in the Peconic Bays of eastern Long Island with otter trawl and hook and line. A detailed description of the gear used was given by Finkelstein (1969).

After a catch was brought aboard, an incision was made in the body cavity of each scup, and sex was determined from a gross, visual inspection of the gonads. Females were subsequently sampled for more detailed examination of their ovaries, the number in a sample being determined by the daily total catch. If the catch of females was large, e.g. 50 to 100, approximately one of every five was randomly selected. If, however, the catch was small, e.g. 5 to 10, then the ovaries were removed from all specimens. After removal, the ovaries were immediately placed in a 10 per cent formalin solution for examination later in the laboratory.

All males and all selected females were measured to the nearest 5 millimeters in fork length and weighed to the nearest ounce on an Ohaus spring scale, model 8004. In addition, approximately 25 scales were removed from the left side of each fish, in the region of the distal portion of the pectoral fin, and placed in a labeled scale envelope. The scales were examined later in the laboratory, and the ages of the fish were determined by the method outlined by Finkelstein (1969).

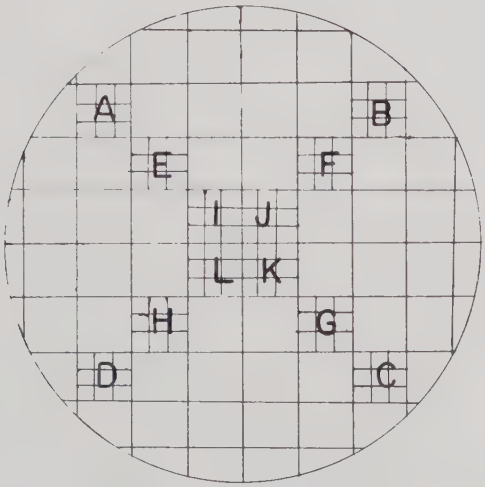

Figure 1. Base of intergrid, disposable petri dish illustrating letters assigned to certain squares.

Upon inspection, males were assigned to arbitrary categories of gonad development as follows: unripe, if the testes were thin, elongated and translucent white to pink, and if no milt could be extruded from the vent under heavy pressure; ripening, if the testes were enlarged, opaquely white, and if some milt could be extruded from the vent under medium pressure; running ripe, if the testes were swollen, white, and if milt flowed freely from the vent under slight or no pressure.

In the laboratory, the eggs within the ovaries were examined to determine the stages of maturity. To avoid the lengthy procedure of sampling eggs from various sections of each ovary, such as that described by Otsu and Uchida (1959), the entire contents of individual ovaries were sampled in the present study. The ovaries were removed from the formalin solution as needed, rinsed in fresh water, blotted dry and weighed to the nearest 0.1 gram on an Ohaus double-pan balance. They were then separated and one of the pair (selected at random) was placed in a watchglass containing Gilson's solution[2], where it was bisected longitudinally and allowed to stand for 1 hour. The eggs then were teased apart from the ovarian tissue with dissecting needles. The solution was stirred to disperse the eggs and 1 cubic centimeter of the mixture was pipetted onto an Intergrid Round Quebec Grid (100 x 15 millimeter) disposable petri dish. To prevent the eggs from moving during subsequent examination, 10 cubic centimeters of a 1 per cent liquid Difco agar solution were poured onto the dish and the resulting mixture was swirled to disperse the eggs. The dish was allowed to cool so that the eggs became embedded in the solidifying agar.

Because the number of eggs in each dish was too large to permit an examination of the entire sample, subsampling was required. This was done as follows: certain of the pre-scribed 1-square-centimeter grid blocks, i.e., those which were further pre-scribed into nine 3.33-square millimeter subdivisions, were assigned letters from A through L (Figure 1). The blocks were stratified according to their distance from the center of the grid (e.g., A-D, E-H, I-L), and one block was randomly selected from each stratum for a total examination of its contents. It is believed that this procedure accounted and adjusted for any disproportionate distribution of eggs by size or number attributable to the sampling technique, such as the possible effects of swirling.

The eggs in each of the selected squares were examined under a binocular microscope at 27-power magnification. Eggs were measured

[2]Gilson's solution, which aids in freeing the eggs from the ovarian tissue, is a mercuric fixative that consists of the following: 88 milliliters of distilled water, 10 milliliters of 95% ethyl alcohol, 2 grams of mercuric chloride, 0.4 milliliters of glacial acetic acid and 1.8 milliliters of nitric acid.

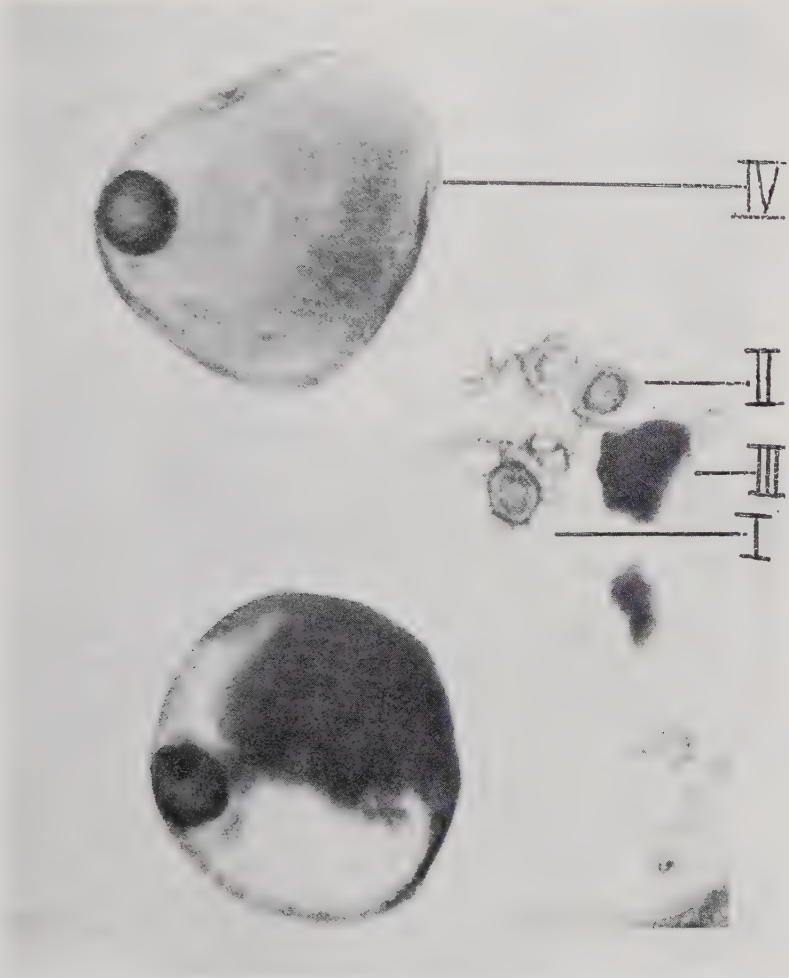

Figure 2. Four types of egg found in an ovary of a 6-year-old scup collected on May 26, 1966. (magnified 30x)

to the nearest 0.01 millimeter in diameter with the aid of an ocular micrometer and assigned to one of four arbitrary developmental types based on morphological characteristics.

When possible, all inspected eggs were enumerated and recorded according to type. Type I eggs were clear, irregular in shape and measured between 0.03 and 0.14 millimeter in diameter; type II eggs were round, with an opaque center (yolk) and translucent periphery, and ranged between 0.11 and 0.33 millimeter in diameter; type III eggs were entirely opaque, yellow, and ranged between 0.31 and

0.63 millimeter in diameter; type IV eggs were entirely translucent, ranged between 0.66 and 0.95 millimeter in diameter, and contained a single oil globule which measured between 0.17 and 0.40 millimeter in diameter. These egg types are illustrated in Figure 2.

In addition, the ratio of ovary weight to total body weight was calculated for each female. Individual ratios were then totaled and averaged for each age group according to the month of collection. Because of insufficient data, however, average monthly ratios are presented graphically for age groups II through V only.

Age frequency distributions were calculated separately for all males and the selected females.

RESULTS

Gonads were examined from 849 male and 440 female scup. Inability to collect sufficient monthly records pertaining to gonad development in any single year necessitated combining the data for all three years. Because of differences in the criteria used, however, the data are presented separately by sex.

Male

The age-frequency distribution of the males that were examined is shown in Figure 3. All age groups between 0 and 15 years were represented in the collections.

Observations on the condition of male gonads relative to age group and month of collection are summarized in Table 1. Male scup as young as 2 years old were observed to be freely exuding milt (running ripe) at capture, an occurrence considered indicative of sexual maturity.

Female

The age-frequency distribution of the females that were examined is shown in Figure 4. All age groups between 0 and 15 years were represented in the collections.

In many instances, type I eggs were too numerous to count. Thus, it was not feasible to derive a frequency distribution of egg types for each female examined. Therefore, observations on the condition of female gonads are presented as the percentages which contained specific egg types in each age group in the monthly samples (Table 2).

All the ovaries contained type I eggs in large numbers, and in 1-year-old fish a few type II eggs were observed in addition. Both type III and type IV eggs were encountered in fish as young as 2 years of age and in all older age groups. Types I and II eggs were found in all specimens in which types III and IV eggs were present.

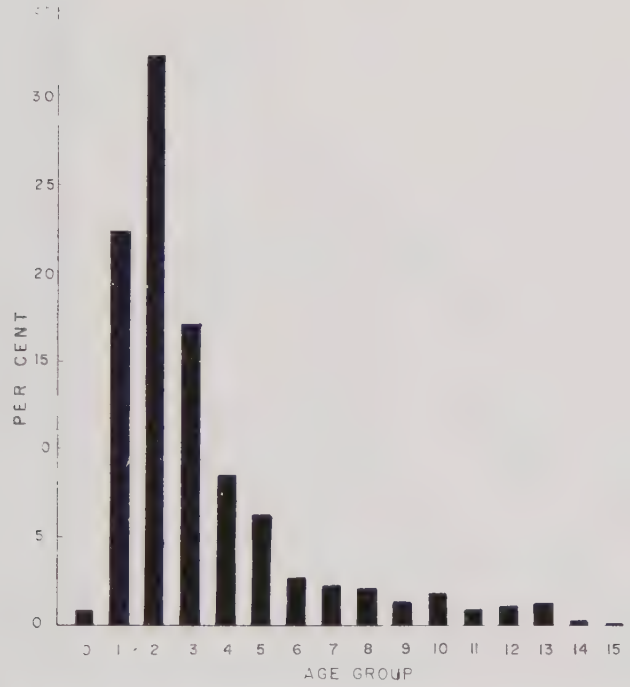

Figure 3. Age-frequency distribution of 849 male scup collected between June 1, 1964 and September 14, 1966.

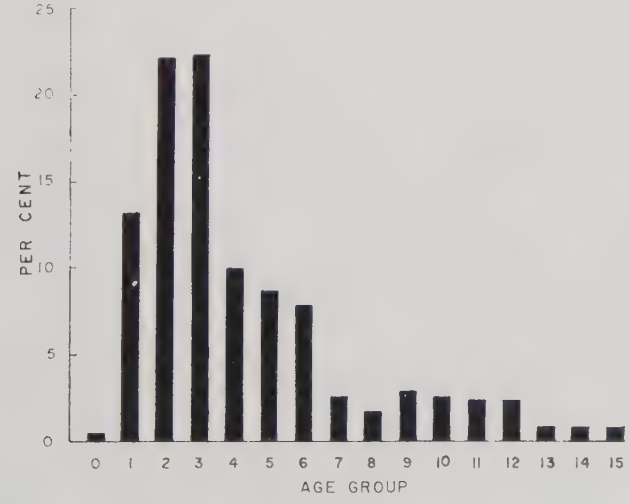

Figure 4. Age-frequency distribution of 440 female scup collected between June 1, 1964 and September 14, 1966.

Table 1. Frequency (in per cent) of Different Stages of Gonad Development According to Age and Month for 849 Male Scup Collected in the Peconic Bays, 1964-1966

Age (years)	May				June				July			
	Number of fish	Stage*			Number of fish	Stage*			Number of fish	Stage*		
		U	R	RR		U	R	RR		U	R	RR
0	0	..	..	..	0	..	..	..	0	..	..	..
1	0	..	..	..	0	..	..	..	54	100.0	0	0
2	4	0	100.0	0	25	60.0	28.0	12.0	108	100.0	0	0
3	4	0	75.0	25.0	97	17.5	61.8	20.6	11	100.0	0	0
4	11	0	81.8	18.2	33	18.2	66.7	15.1	14	92.8	7.2	0
5	17	0	82.3	17.6	18	11.1	50.0	38.9	5	80.0	20.0	0
6	10	0	70.0	30.0	8	0	75.0	25.0	1	100.0	0	0
7	8	0	62.5	37.5	4	0	75.0	25.0	2	100.0	0	0
8	7	0	71.4	28.6	4	0	75.0	25.0	2	100.0	0	0
9	5	0	100.0	0	3	0	33.3	66.7	0	..	..	..
10	7	0	14.2	85.7	3	0	100.0	0	3	100.0	0	0
11	4	0	50.0	50.0	2	0	100.0	0	0	..	..	..
12	4	0	75.0	25.0	2	0	50.0	50.0	2	100.0	0	0
13	8	0	62.5	37.5	0	..	..	..	2	100.0	0	0
14	1	0	100.0	0	0	..	..	..	1	100.0	0	0
15	1	0	100.0	0	0	..	..	..	0	..	..	..
Total	91	xxx	xxx	xxx	199	xxx	xxx	xxx	205	xxx	xxx	xxx

TABLE 1. (*continued*)

Age (years)	August				September				October				Total number of fish
	Number of fish	Stage*			Number of fish	Stage*			Number of fish	Stage*			
		U	R	RR		U	R	RR		U	R	RR	
0	0	..	..	..	0	..	..	..	6	100.0	0	0	6
1	53	100.0	0	0	56	100.0	0	0	27	100.0	0	0	190
2	116	100.0	0	0	21	100.0	0	0	0	..	..	..	274
3	26	100.0	0	0	7	100.0	0	0	0	..	..	..	145
4	9	100.0	0	0	4	100.0	0	0	0	..	..	..	71
5	9	100.0	0	0	3	100.0	0	0	0	..	..	..	52
6	1	100.0	0	0	2	100.0	0	0	0	..	..	..	22
7	4	100.0	0	0	1	100.0	0	0	0	..	..	..	19
8	2	100.0	0	0	2	100.0	0	0	0	..	..	..	17
9	3	100.0	0	0	0	..	..	..	0	..	..	..	11
10	1	100.0	0	0	0	..	..	..	0	..	..	..	14
11	0	..	..	..	0	..	..	..	0	..	..	..	6
12	1	100.0	0	0	0	..	..	..	0	..	..	..	9
13	0	..	..	..	0	..	..	..	0	..	..	..	10
14	0	..	..	..	0	..	..	..	0	..	..	..	2
15	0	..	..	..	0	..	..	..	0	..	..	..	1
Total	225	xxx	xxx	xxx	96	xxx	xxx	xxx	33	xxx	xxx	xxx	849

* U = unripe; R = ripening; RR = running ripe.

TABLE 2. FREQUENCY (IN PER CENT) OF DIFFERENT EGG TYPES ACCORDING TO AGE AND MONTH FOR 440 FEMALE SCUP COLLECTED IN THE PECONIC BAYS, 1964-1966

Age (years)	May					June					July				
	Number of fish	Type				Number of fish	Type				Number of fish	Type			
		I	II	III	IV		I	II	III	IV		I	II	III	IV
0	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..
1	0	..	..	..	..	0	..	..	..	..	8	100.0	0	0	0
2	1	100.0	100.0	100.0	0	23	100.0	73.9	26.1	13.0	50	100.0	70.0	0	0
3	8	100.0	100.0	75.0	50.0	68	100.0	95.6	64.7	2.9	6	100.0	66.7	0	0
4	11	100.0	100.0	81.8	72.7	23	100.0	100.0	78.3	13.0	3	100.0	100.0	33.3	33.3
5	10	100.0	100.0	90.0	40.0	21	100.0	100.0	71.4	9.5	2	100.0	50.0	0	0
6	13	100.0	100.0	92.3	23.1	18	100.0	100.0	88.9	22.2	1	100.0	100.0	0	0
7	6	100.0	100.0	83.3	33.3	3	100.0	66.7	66.7	0	1	100.0	100.0	0	0
8	3	100.0	100.0	100.0	66.7	3	100.0	100.0	100.0	0	1	100.0	0	0	0
9	8	100.0	100.0	87.5	25.0	2	100.0	100.0	100.0	0	1	100.0	100.0	0	0
10	5	100.0	100.0	100.0	20.0	3	100.0	100.0	100.0	0	2	100.0	100.0	0	0
11	3	100.0	100.0	66.7	33.3	6	100.0	100.0	100.0	16.7	1	100.0	100.0	0	0
12	2	100.0	100.0	100.0	50.0	8	100.0	100.0	100.0	25.0	0	..	..	..	..
13	0	..	..	..	..	2	100.0	100.0	100.0	50.0	0	..	..	..	..
14	3	100.0	100.0	100.0	33.3	0	..	..	..	..	0	..	..	..	..
15	3	100.0	100.0	100.0	100.0	0	..	..	..	..	0	..	..	..	..
Total	76	xxx	xxx	xxx	xxx	180	xxx	xxx	xxx	xxx	76	xxx	xxx	xxx	xxx

TABLE 2. *(continued)*

Age (years)	August					September					October					Total number of fish
	Number of fish	Type				Number of fish	Type				Number of fish	Type				
		I	II	III	IV		I	II	III	IV		I	II	III	IV	
0	0	..	..	..	..	0	..	..	..	..	2	100.0	0	0	0	2
1	22	100.0	4.5	0	0	5	100.0	40.0	0	0	23	100.0	26.1	0	0	58
2	17	100.0	64.7	0	0	3	100.0	66.7	0	0	1	100.0	100.0	0	0	95
3	10	100.0	30.0	0	0	7	100.0	71.4	0	0	0	..	..	..	..	99
4	6	100.0	50.0	0	0	2	100.0	100.0	0	0	0	..	..	..	..	45
5	4	100.0	50.0	0	0	0	..	..	..	..	0	..	..	..	..	37
6	1	100.0	100.0	0	0	1	100.0	0	0	0	0	..	..	..	..	34
7	1	100.0	0	0	0	0	..	..	..	..	0	..	..	..	..	11
8	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..	7
9	1	100.0	0	0	0	0	..	..	..	..	0	..	..	..	..	12
10	1	100.0	0	0	0	0	..	..	..	..	0	..	..	..	..	11
11	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..	10
12	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..	10
13	1	100.0	100.0	0	0	0	..	..	..	..	0	..	..	..	..	3
14	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..	3
15	0	..	..	..	..	0	..	..	..	..	0	..	..	..	..	3
Total	64	xxx	xxx	xxx	xxx	18	xxx	xxx	xxx	xxx	26	xxx	xxx	xxx	xxx	440

Type III eggs were found in ovaries collected on the first sampling dates each year, i.e., June 1 in 1964, May 7 in 1965 and May 11 in 1966. They were last observed in ovaries taken on June 25 in 1964, June 18 in 1965 and July 15 in 1966. Similarly, type IV eggs were first observed in ovaries collected on June 3 in 1964, May 10 in 1965 and May 11 in 1966, while they were last observed on June 25 in 1964, June 11 in 1965 and July 15 in 1966.

Monthly averages of the ovary weight-body weight relationship are presented for age groups II through V in Figure 5. Average ratios of ovary weight to body weight were highest during May, but then they decreased rather sharply through June to July when they became stabilized at a low level through September. The high ratios of May and June coincided well with the presence of large numbers of types III and IV eggs in the ovaries.

DISCUSSION

The morphological differences observed in scup eggs suggest that they undergo certain developmental changes within the ovary as they approach maturity. The eggs progress from type I, through the intermediary stages of types II and III, and finally develop into type IV. Thus, type III eggs are probably developed prior to the spawning period, but they evolve into type IV immediately before spawning commences.

The eggs assigned to type IV ranged from 0.66 to 0.95 millimeter in diameter. These sizes are in close accord with those reported for spawned eggs collected in the natural environment. Kuntz and Radcliff (1917) recorded a range of 0.85 to 0.90 millimeter for scup eggs obtained at Woods Hole, Massachusetts, while Perlmutter (1939) stated that the 66 scup eggs he collected in Long Island waters ranged from 0.80 to 0.96 millimeter. Moreover, Wheatland (1956) collected eggs in Long Island Sound which measured between 0.85 and 1.15 millimeters, and Herman (1963) found scup eggs from 0.85 to 1.05 millimeters in diameter in material from Narragansett Bay.

Many of the type IV eggs reported here were smaller than those collected by the foregoing authors. The eggs examined in this study, however, were removed from the ovaries prior to spawning, while those in the other studies were from samples collected in the sea after spawning. The sea eggs were older and undoubtedly had absorbed some water and would be larger than the eggs found within the ovaries. Thus, since the type IV eggs in this study were similar in size and appearance to spawned eggs reported by other authors, and since they were found in the ovaries at approximately the same time as mature eggs were found in the water, it seems reasonable

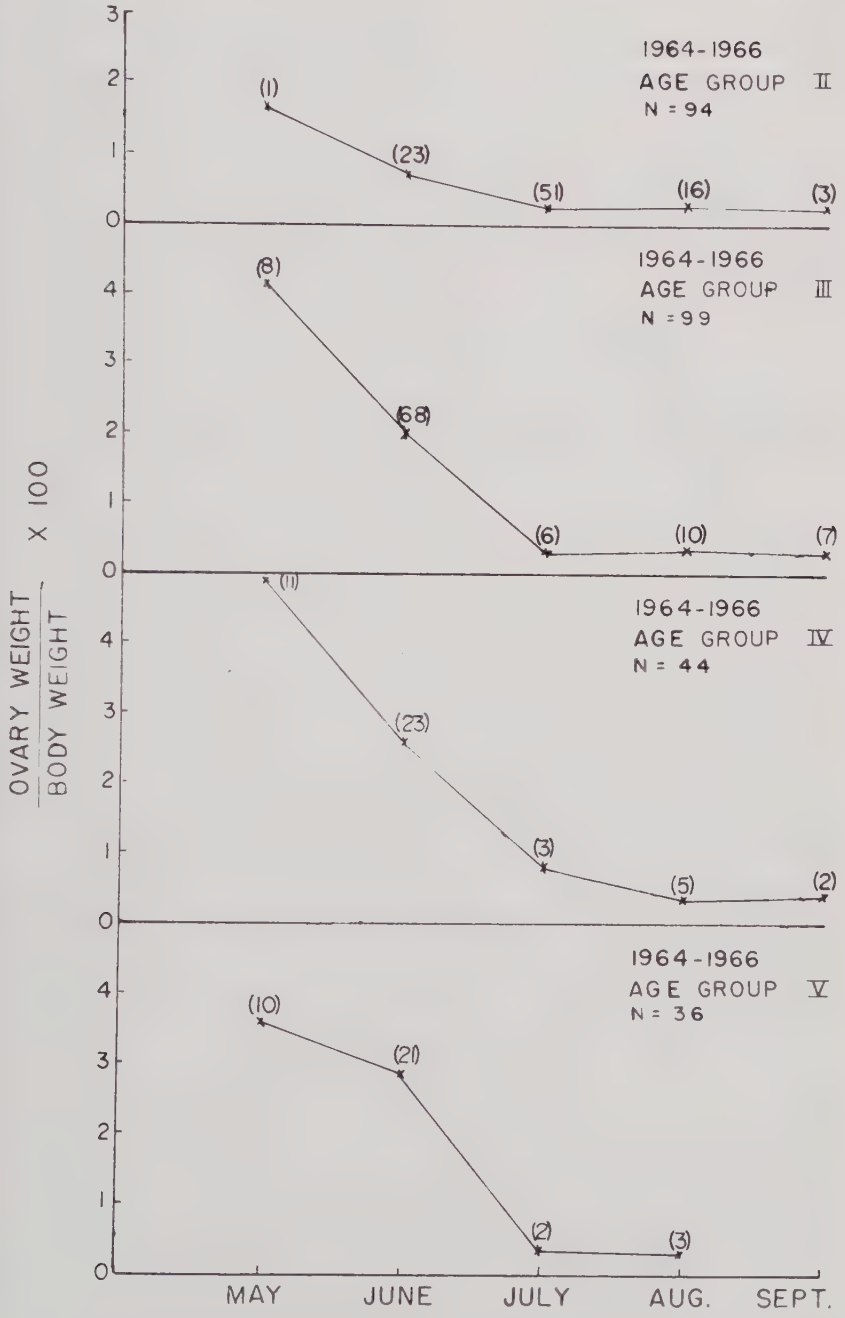

Figure 5. Average monthly ovary weight-body weight ratios according to age group for 273 scup, 2 to 5 years old, collected between June 1, 1964 and September 14, 1966. (Numbers in parentheses represent sample size.)

to conclude that eggs assigned to type IV on the basis of the criteria used are mature eggs.

If it is assumed that spawning begins at the first appearance in the ovary of type IV eggs and terminates with the disappearance of all type III and type IV eggs, then the period of spawning can be delineated. Thus, in the Peconic Bays, spawning most probably occurred between May 10 and June 18 in 1965, and between May 11 and July 15 in 1966. Although spawning appeared to commence at approximately the same time during these two years, the peak of spawning probably occurred later in 1966 than in 1965. Most of the large spawning fish did not arrive in the Peconic Bays until about 2 weeks later in 1966 than in the previous year (Finkelstein, 1969). Unfortunately, data are lacking for May 1964. Consequently, the date (June 3) on which type IV eggs were first observed in 1964 should not be construed as that on which spawning commenced. However, the latest observation date for types III and IV eggs in 1964 was June 25, suggesting that the terminal date of spawning coincided roughly with that in 1965 and 1966.

Others who have studied the spawning period of scup have arrived at dates which correspond closely to those derived from the present work. Nichols and Breder (1926) stated that the scup "Spawns early in June (Woods Hole); males with running milt June 1 to 23 (Sandy Hook Bay)." Perlmutter (1939) observed that scup spawned in Long Island waters from May to August, with the height of spawning in June. Wheatland (1956) studied egg collections from Long Island Sound and found indications that the spawning period of scup extended from the end of May to the end of July in 1952, and from the beginning of June to the first week of July in 1953. Bigelow and Schroeder (1953) further indicated that "Along southern New England scup spawn from May to August, but chiefly in June. Probably spawning both commences later and continues later for the few fish that manage to summer in Massachusetts Bay, and it may be assumed that they spawn wherever they summer."

CONCLUSIONS

Since mature eggs (type IV) were found in their ovaries, it would appear that some female scup attain sexual maturity as young as age II. This conclusion is further supported by the observed decrease in the ovary weight-body weight ratio for 2-year-olds which occurred during the spawning period and coincided with similar decreases in this ratio for older age groups. Furthermore, since types III and IV eggs were encountered in most specimens of all age groups above age II during the spawning periods, it seems reasonable to conclude

that most female scup of all ages between 2 and 15 years (the oldest specimen examined) spawn each year and at approximately the same time (May to July). There was no discernable pattern of older fish spawning earlier or later than younger fish.

Since 2-year-old males were assigned to both "ripening" and "running ripe" categories of gonad development, it appears that male scup attain sexual maturity at the same age as female scup.

Aspects of egg resorption and fecundity are problems which must await further study.

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THE SPORT FISHERIES FOR TAUTOG IN THE INSHORE WATERS OF EASTERN LONG ISLAND[1]

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ABSTRACT

The sport fisheries for tautog in the inshore waters of eastern Long Island were studied between May 1 and November 30 from 1964 through 1966. Tautog were important to anglers in these waters both as a supplementary species during the summer and as the principal species in the fall. Anglers often fished for tautog when fishing for other species was poorer than expected. Eastern Long Island Sound from Truman Beach through Plum Gut was heavily fished for tautog. In the study area, the species generally ranked third in numbers of fish caught behind scup and winter flounder. Anglers fishing from rowboats and Greenport-based open boats fished for tautog to a greater degree than anglers using other fishing facilities. Although tautog were taken from May through November, the catch and catch per effort were greatest in the fall. The average size of tautog in the sport fisherman's catches was greatest in May, declined in the summer and increased in the fall.

The sport fisheries for tautog (*Tautoga onitis*) in the inshore waters of eastern Long Island were studied between May 1 and November 30 from 1964 through 1966. The purpose of the study was to obtain estimates of catch and catch per effort as a part of the basic information needed for management recommendations. The study area encompassed all the waters enclosed by the dashed line in Figure 1. Except for surf fishing east of Montauk Harbor Inlet, all angling within this area was included in the study. The survey area was the same as that covered by Briggs (1968) in a study of the sport fisheries for scup *(Stenotomus chrysops).*

METHODS

Conservation Department personnel conducted a roving creel census daily (during daylight hours only) between May 1 and November 30 from 1964 through 1966. The data collected from anglers interviewed during this census were used to estimate the catch per effort (numbers of fish per angler per trip) for tautog and other species for each of the various sport fishing facilities (bank and pier, rowboat, open boat, charter boat and private boat), the proportion of anglers that sought tautog for each facility and the proportion of tautog in their catches. The data also were used to determine the numbers of anglers per boat for each of the boat facilities. Anglers whose trips were less than 4 hours duration were not recorded because this time period was arbitrarily considered to be the minimum length for an angler trip.

[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

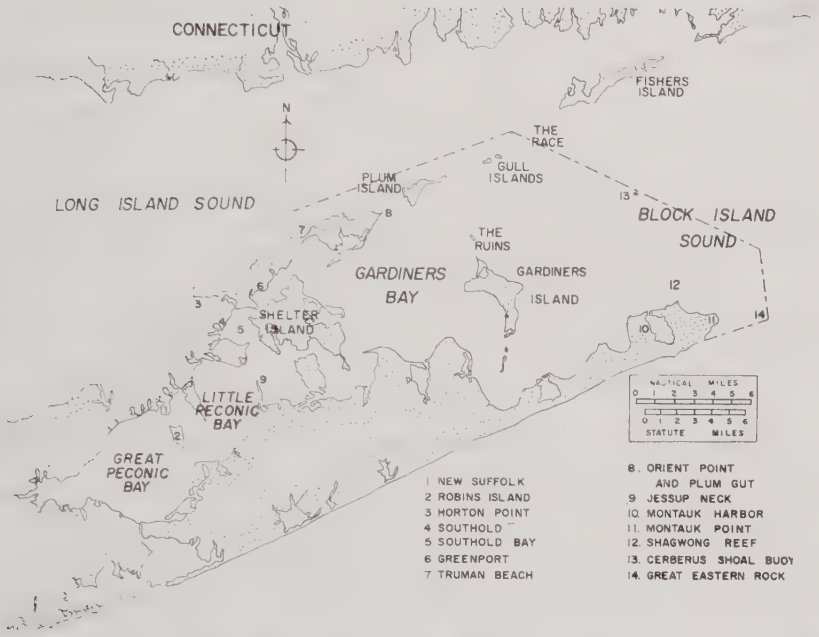

Figure 1. Map of eastern Long Island showing study area (limits indicated by dash line) and important locations in it.

An aerial census of anglers and boats was conducted during the same time period as the creel census. A total of 84 randomly scheduled flights (28 each year) were distributed equally by month to include both weekday and weekend day sampling (holidays were considered as weekend days). This resulted in two flights on weekdays and two flights on weekend days each month. The aerial observations provided instantaneous counts of anglers fishing from banks and piers and of boats of various types engaged in sport fishing in the area. Using the method described by Briggs (1962), the flight data were expanded in conjunction with the data collected by personal interviews to determine estimates of the total number of anglers fishing for tautog and the total catch of tautog.

In addition to collecting data on the numbers of anglers and the numbers of fish they caught, tautog were selected randomly from anglers' catches and measured to the nearest 5 millimeters (0.2 inch) in total length at rowboat stations at New Suffolk, Southold and near Orient Point on Long Island Sound for a length-weight study (Briggs, 1969).

For the purposes of this study, the terms "summer" and "fall" do not correspond to their proper calendar dates. Rather, summer re-

fers to the period May 1 through August 31 and fall refers to the period September 1 through November 30.

FISHING FACILITIES

The facilities available to sport fishermen in the study area were previously described by Briggs (1968). The types of boats available were the same as described by Briggs (1962). The majority of open boats and charter boats were berthed at Montauk Harbor, with a smaller fleet of these craft available in and around Greenport. Most of the rowboat rental facilities were in the Peconic Bays, with concentrations at Southold and New Suffolk. These and other sites mentioned in this study are shown in Figure 1.

THE TAUTOG FISHERIES

In May, anglers using rowboats, private boats and Greenport-based open boats and charter boats fished primarily in the area of Jessup Neck. The tautog landed at this time were usually considered supplemental to catches of the more desired scup. After May, open boats and charter boats from Greenport generally concentrated their efforts either at Plum Gut, the Gull Islands, The Race, The Ruins or along the coast of Gardiners Island. Tautog taken from June through August by anglers aboard the open boats and charter boats were taken mostly to augment catches of scup, summer flounder (*Paralichthys dentatus*) and bluefish (*Pomatomus saltatrix*).

The inshore waters of Long Island Sound from Truman Beach through Plum Gut and along the northwestern shore of Plum Island were heavily fished each year for tautog. From mid-June through November, anglers in skiffs launched from two rowboat stations near Orient Point fished in this area for tautog. In the fall, anglers aboard Greenport-berthed open boats and charter boats fished heavily in these waters for tautog. Passengers aboard such boats from Connecticut also fished in this area occasionally in the fall.

Another area of some importance to anglers who sought tautog is in the northeastern corner of Southold Bay. This area, locally called "The Brickyard", was fished by anglers who rented rowboats from stations at Southold. Although it was fished throughout the year, The Brickyard was fished most heavily in the fall.

A few anglers who rented rowboats at New Suffolk fished for tautog near Robins Island. The anglers aboard open boats from Montauk Harbor caught tautog in the vicinities of Montauk Point and Great Eastern Rock while fishing primarily for scup. The only areas where anglers consistently fished for tautog from banks were at Truman Beach and in the vicinity of Orient Point on Long Island Sound.

Analysis of Fishing Effort

Data derived from interviews with 18,078 sport fishermen and 84 census flights indicate that the estimated number of anglers who sought tautog (Table 1) decreased from 50,436 in 1964 to 26,076 in 1965 and then increased in 1966 to 34,096. Most of the decline in the estimated number of anglers occurred in the summer.

Except for June and July of 1964, less than a quarter of all anglers fished for tautog during any summer month (Table 2). Increases in effort generally occurred in the fall. At that time, usually well over half of all the anglers aboard open boats and rowboats fished for tautog.

In 1964, the differences between the total numbers of anglers who sought tautog from each of the boat facilities were small. However, in 1965 and 1966, open boats and rowboats were used by well over half of all anglers who fished for tautog. Relatively few anglers fished for tautog from banks and piers.

Anglers who sought tautog comprised a much greater percentage of all anglers fishing from open boats and charter boats berthed at Greenport than from similar facilities at Montauk Harbor (Table 3). Fishermen aboard the Montauk Harbor-based boats often did not seek tautog even when fishing over grounds where the species was present.

Analysis of Catch

The estimated catch of tautog by sport fishermen (Table 4) decreased from 306,947 fish in 1964 to 145,769 in 1965 and then increased to 188,075 in 1966. The variations in the sport catch generally paralleled the variations in the estimated numbers of anglers seeking tautog. Somewhat lower catch rates, however, also appeared to be a factor in the lower tautog landings observed for 1965 and 1966 (see Table 6).

Each year, the highest catches of tautog were made in the fall. In 1964 and 1965, peak catches were made in October. In 1966, more tautog were caught in September than in any other month. During the summer, tautog generally constituted a very small portion (usually less than 10 per cent) of the catch of all species by all anglers.

Anglers fishing from open boats landed more tautog (from 41 to 48 per cent of all tautog caught) than anglers using any other facility. Anglers fishing from banks and piers caught relatively few tautog (only from 2 to 4 per cent of all tautog landed).

Although tautog constituted only 14 per cent of all fish landed by sport fishermen in the study area in 1964, 6 per cent in 1965 and 11

TABLE 1. ESTIMATED NUMBER OF ANGLERS WHO SOUGHT TAUTOG EACH MONTH ACCORDING TO FACILITY

Facility	Month							Total	
	May	June	July	August	September	October	November	Number	Per cent
1964									
Bank and Pier	110	292	485	613	1,260	678	174	3,612	7
Rowboat	662	1,456	2,480	2,722	2,126	852	828	11,126	22
Open boat	416	2,294	1,526	2,127	1,466	2,717	2,215	12,761	25
Charter boat	1,504	2,755	2,649	1,176	852	1,668	789	11,393	23
Private boat	2,297	2,534	3,447	1,425	546	706	589	11,544	23
Total	4,989	9,331	10,587	8,603	6,250	6,621	4,595	50,436	100
1965									
Bank and Pier	810	200	327	349	472	532	53	2,743	11
Rowboat	1,711	812	1,390	535	1,743	1,334	286	7,811	30
Open boat	0	203	1,856	779	1,380	1,748	1,050	7,016	27
Charter boat	0	201	718	352	872	756	818	3,717	14
Private boat	1,307	596	627	756	537	751	245	4,789	18
Total	3,828	2,012	4,918	2,771	5,004	5,091	2,452	26,076	100
1966									
Bank and Pier	114	262	381	506	376	218	31	1,888	5
Rowboat	1,608	291	1,388	1,479	2,225	1,199	346	8,536	25
Open boat	191	207	1,644	1,878	6,242	2,746	957	13,865	40
Charter boat	409	216	1,954	256	1,004	857	275	4,971	14
Private boat	1,907	344	1,174	332	793	669	427	5,646	16
Total	4,229	1,320	6,541	4,451	10,640	5,689	2,036	34,906	100

TABLE 2. PERCENTAGES OF ALL ANGLERS IN EACH FACILITY EACH MONTH WHO SOUGHT TAUTOG

Facility	Month							Season
	May	June	July	August	September	October	November	
1964								
Bank and pier	7	16	17	13	29	58	32	21
Rowboat	7	37	31	39	54	79	71	32
Open boat	16	64	30	45	74	89	97	54
Charter boat	44	65	35	14	21	42	28	33
Private boat	24	41	26	10	8	22	25	20
Total	19	47	29	20	29	53	50	30
1965								
Bank and pier	28	13	14	13	14	32	11	18
Rowboat	14	24	22	8	42	71	47	22
Open boat	0	10	30	7	25	61	100	22
Charter boat	0	14	22	6	15	19	44	15
Private boat	12	10	7	6	6	13	11	8
Total	12	14	18	7	17	32	40	16
1966								
Bank and pier	7	14	16	15	11	25	10	14
Rowboat	20	6	24	28	58	59	57	28
Open boat	5	10	33	38	83	61	80	47
Charter boat	21	8	46	5	14	18	25	19
Private boat	22	4	11	3	8	17	25	10
Total	17	7	23	15	33	35	42	23

per cent in 1966 (Table 5), they were exceeded in the catch only by scup and winter flounder (*Pseudopleuronectes americanus*) in 1964 and 1966, and scup, winter flounder and bluefish in 1965 (Briggs, 1969).

ANALYSIS OF CATCH PER EFFORT

Catch per effort for tautog (Table 6) generally was lowest during the summer for anglers using all facilities. This is apparently normal for angling for this fish. Briggs (1962) found a similar situation for the sport fisheries of Great South Bay. Moreover, Bigelow and

TABLE 3. PERCENTAGE OF ALL ANGLERS, FISHING FROM OPEN BOATS AND CHARTER BOATS BERTHED IN THE VICINITY OF GREENPORT AND AT MONTAUK HARBOR, WHO SOUGHT TAUTOG

Facility and berth	May	June	July	August	September	October	November
1964							
Open boat							
Greenport	22	87	52	86	89	100	97
Montauk Harbor	0	27	18	12	54	58	*
Charter boat							
Greenport	100§	92	51	24	33	88	54
Montauk Harbor	22	0	0	3	10	16	6
1965							
Open boat							
Greenport	0	16	62	18	69	93	100
Montauk Harbor	0	21	11	3	8	13	*
Charter boat							
Greenport	0	24	27	10	20	40	71
Montauk Harbor	0	5	14	0	6	0	0
1966							
Open boat							
Greenport	5	10	60	69	100	98	85
Montauk Harbor	*	0	0	25	75	27	0
Charter boat							
Greenport	17	15	78	14	22	50	91
Montauk Harbor	41	0	0	0	0	0	3

* Anglers using this facility at this time did not fish in the study area.
§ Anglers aboard only one boat were interviewed.

Schroeder (1953) noted that, while angling for tautog started in late April or early May in the southern reaches of the Gulf of Maine, the best catches were made later in the year. In the present study, the best catch rates usually were attained in October and November.

Briggs (1962) found that anglers who fished from banks and piers on Great South Bay caught tautog at a rate as good or better than anglers who used boats on the bay. In the present study, a similar pattern was noted, at times, during the summer. In May of 1964 and 1965, for example, anglers fishing from banks and piers attained higher catch rates than anglers who used other facilities. Throughout the remainder of the summer and in May of 1966, however,

TABLE 4. ESTIMATED SPORT CATCH OF TAUTOG EACH MONTH ACCORDING TO FACILITY

Facility	Month							Total	
	May	June	July	August	September	October	November	Number	Per cent
1964									
Bank and Pier	767	396	499	1,148	2,639	1,525	422	7,696	3
Rowboat	4,337	3,264	5,479	4,517	12,523	7,409	7,390	44,919	15
Open boat	3,335	6,692	5,636	5,664	9,783	48,459	17,113	126,682	41
Charter boat	6,287	14,453	10,089	3,692	6,827	22,191	9,476	73,015	24
Private boat	10,718	10,229	10,437	3,747	2,404	8,008	9,092	54,635	18
Total	25,444	35,034	32,140	19,068	34,176	87,592	73,493	306,947	100
1965									
Bank and Pier	2,168	151	322	445	858	1,240	39	5,223	4
Rowboat	3,449	2,600	3,040	1,578	9,419	12,193	2,992	35,271	24
Open boat	661	2,135	8,633	2,636	18,565	21,173	10,169	63,972	44
Charter boat	706	724	3,631	2,924	5,420	7,321	5,734	26,460	18
Private boat	2,241	1,301	2,508	549	1,987	4,619	1,638	14,843	10
Total	9,225	6,911	18,134	8,132	36,249	46,546	20,572	145,769	100
1966									
Bank and Pier	150	367	570	736	609	765	25	3,222	2
Rowboat	6,288	1,759	3,790	3,256	9,719	8,254	2,878	35,944	19
Open boat	2,865	1,829	5,582	5,555	35,723	25,620	13,398	90,572	48
Charter boat	3,477	1,367	7,814	601	7,913	6,925	2,709	30,806	16
Private boat	10,280	1,999	2,521	752	3,059	4,411	4,509	27,531	15
Total	23,060	7,321	20,277	10,900	57,023	45,975	23,519	188,075	100

TABLE 5. PERCENTAGE OF TAUTOG IN THE CATCH OF ALL SPECIES FOR EACH FACILITY EACH MONTH

Facility	Month							Season
	May	June	July	August	September	October	November	
1964								
Bank and pier	12	4	3	7	12	38	17	9
Rowboat	2	6	4	5	22	56	56	7
Open boat	6	9	6	5	21	71	70	24
Charter boat	11	24	11	6	17	54	36	19
Private boat	7	14	8	3	5	33	31	9
Total	5	13	7	4	16	58	53	14
1965								
Bank and pier	15	2	4	4	3	19	2	6
Rowboat	2	6	4	2	21	49	38	7
Open boat	2	5	6	1	9	62	52	7
Charter boat	2	4	9	6	9	25	35	10
Private boat	1	2	4	1	4	10	6	3
Total	2	4	5	1	10	33	29	6
1966								
Bank and pier	3	4	7	5	2	23	3	5
Rowboat	3	1	8	10	30	43	51	8
Open boat	3	7	18	10	24	32	63	20
Charter boat	7	6	40	3	14	26	54	15
Private boat	5	3	6	1	5	19	37	6
Total	4	3	14	6	18	30	53	11

anglers aboard charter boats usually had higher catch rates than anglers who used other facilities. Anglers fishing from boats, especially open boats, had the highest catch rates in the fall.

SIZE

Examination of the size composition of 3,228 tautog landed by anglers using rowboats indicated that this fish entered the sport fisheries in numbers at about 200 millimeters (7.9 inches) in length, although some as small as 150 millimeters (5.9) inches were retained

TABLE 6. CATCH PER EFFORT FOR TAUTOG EACH MONTH ACCORDING TO FACILITY*

Facility	May	June	July	August	September	October	November
				1964			
Bank and pier	5.0	0.7	0.8	2.1	2.1	2.1	2.4
Rowboat	1.7	1.9	1.8	1.4	5.8	8.7	8.9
Open boat	4.2	2.9	2.4	2.4	6.7	17.8	21.3
Charter boat	4.2	5.3	3.6	2.9	8.0	13.3	12.0
Private boat	4.2	4.0	2.8	2.6	3.9	11.4	15.4
				1965			
Bank and pier	2.0	0.4	0.9	1.2	1.4	2.3	0.8
Rowboat	1.1	2.9	1.8	2.1	5.3	9.1	10.4
Open boat	§	7.1	3.4	3.0	10.6	12.1	9.7
Charter boat	§	3.5	5.0	8.4	6.2	9.7	7.0
Private boat	1.6	1.5	3.8	0.7	3.7	6.4	6.7
				1966			
Bank and pier	1.3	1.1	1.2	1.5	1.5	3.5	0.8
Rowboat	2.1	1.4	2.0	2.0	4.2	6.7	8.3
Open boat	0.6	4.4	3.2	2.6	5.7	9.2	14.0
Charter boat	4.8	4.9	4.3	1.9	7.8	8.0	9.7
Private boat	4.1	2.0	1.7	1.6	3.8	6.6	10.3

* Since catch per effort (number of fish per angler per trip) was derived solely from the catch of tautog by anglers seeking them, and since many tautog were landed incidentally by anglers seeking other species, multiplication of the catch rates given here by the estimated numbers of anglers seeking tautog (Table 1) does not necessarily result in the estimated catches shown in Table 4.

§ Tautog were not actively sought by anglers who used this facility at this time. Any tautog caught by them were taken incidentally while other species were sought.

(Figures 2 to 4). Anglers landed relatively few tautog over 500 millimeters (19.7 inches). The largest tautog recorded in this study was 630 millimeters (24.8 inches) and weighed 5,642 grams (12 pounds 7 ounces). Anglers fishing for tautog in May caught few fish under 350 millimeters (13.8 inches). However, after May, fish under 350 millimeters comprised the bulk of all tautog landed.

The average total length of tautog landed by sport fishermen each month during the study period is given in Table 7. An analysis of variance (Table 8) indicated that there were significant differences between the average monthly sizes. The locations of these differences were determined by "*t*" tests (Tables 9 and 10). Mean length was greatest in May, over 400 millimeters (15.8 inches) each year. There

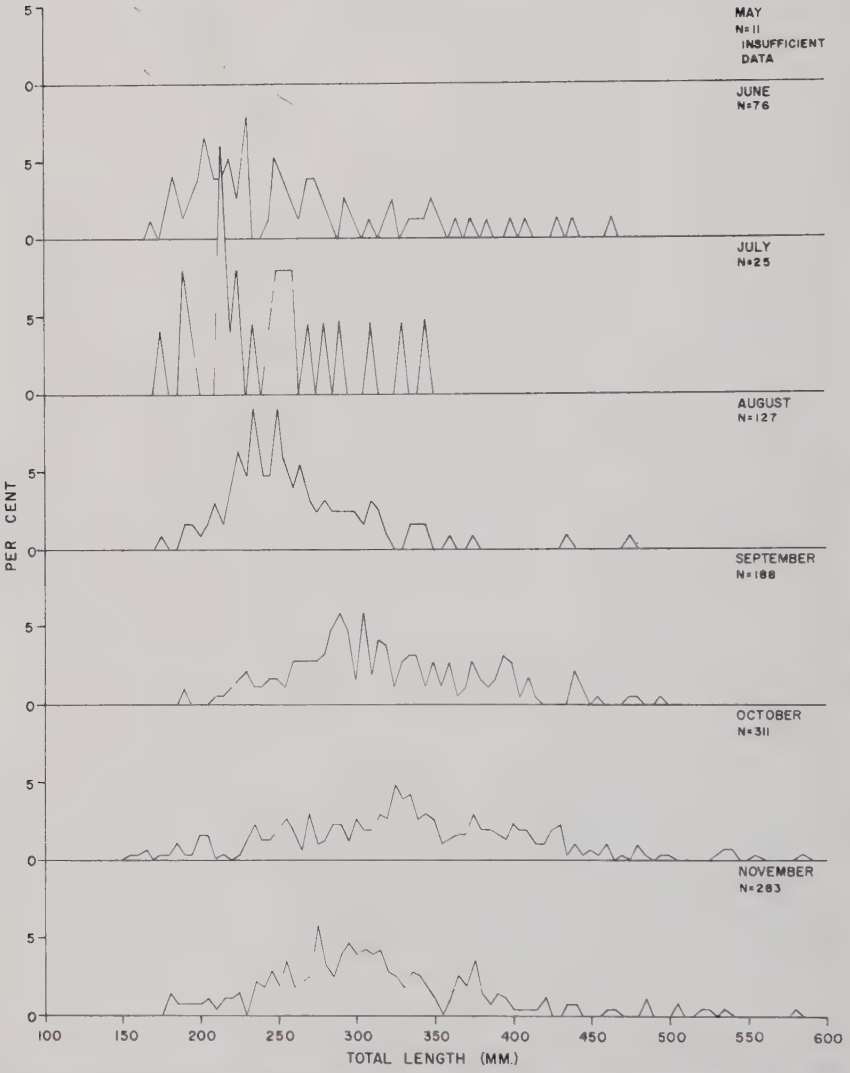

Figure 2. Monthly length-frequency distribution of tautog caught by sport fishermen in 1964.

was a significant reduction in the average monthly size of tautog landed between May and June of each year. The smallest mean lengths were recorded from June through August. However, apparent changes in average size between June and August generally did not prove to be significant. In 1964 and 1966, there was a significant increase in the average size of tautog landed by anglers in September as compared with that between June and August. In 1965, how-

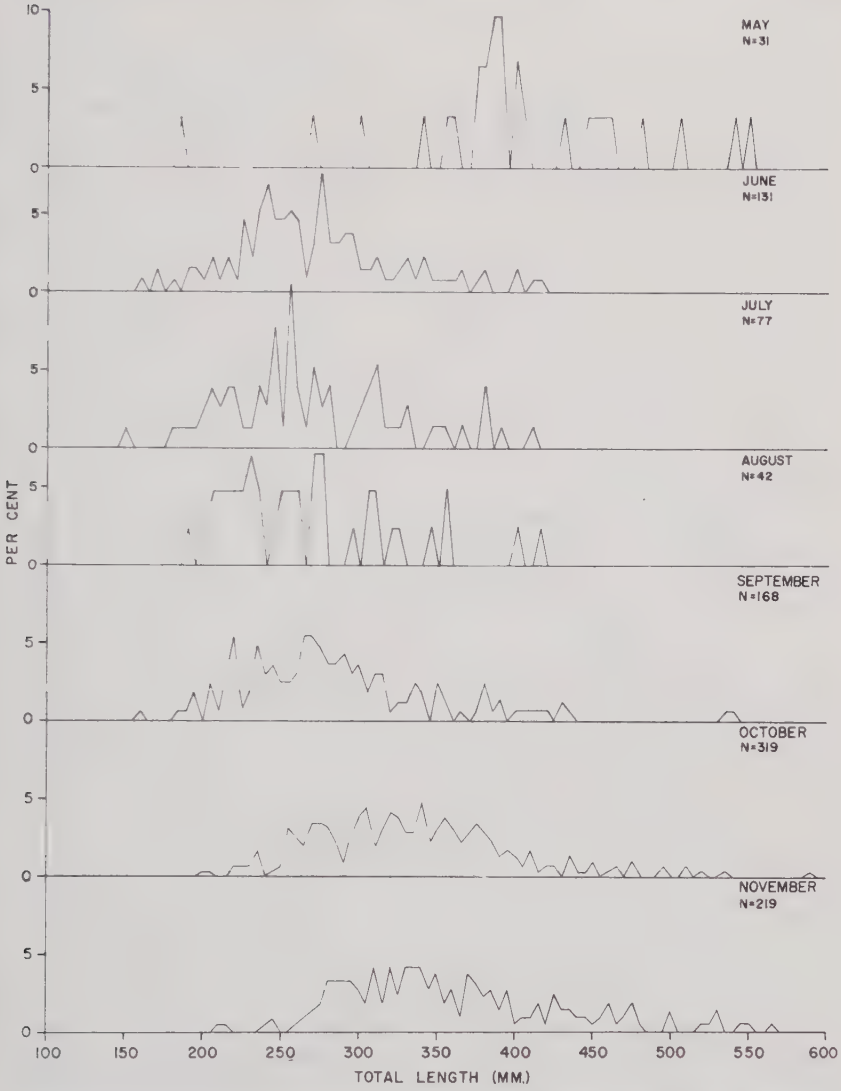

Figure 3. Monthly length-frequency distribution of tautog caught by sport fishermen in 1965.

ever, the average size did not show a significant increase in the fall until October. The reduction in average size during the summer suggests that the larger fish may seek deeper, cooler water and thus not be available to the fishermen at that time.

DISCUSSION

The tautog fishing season extended from May through November.

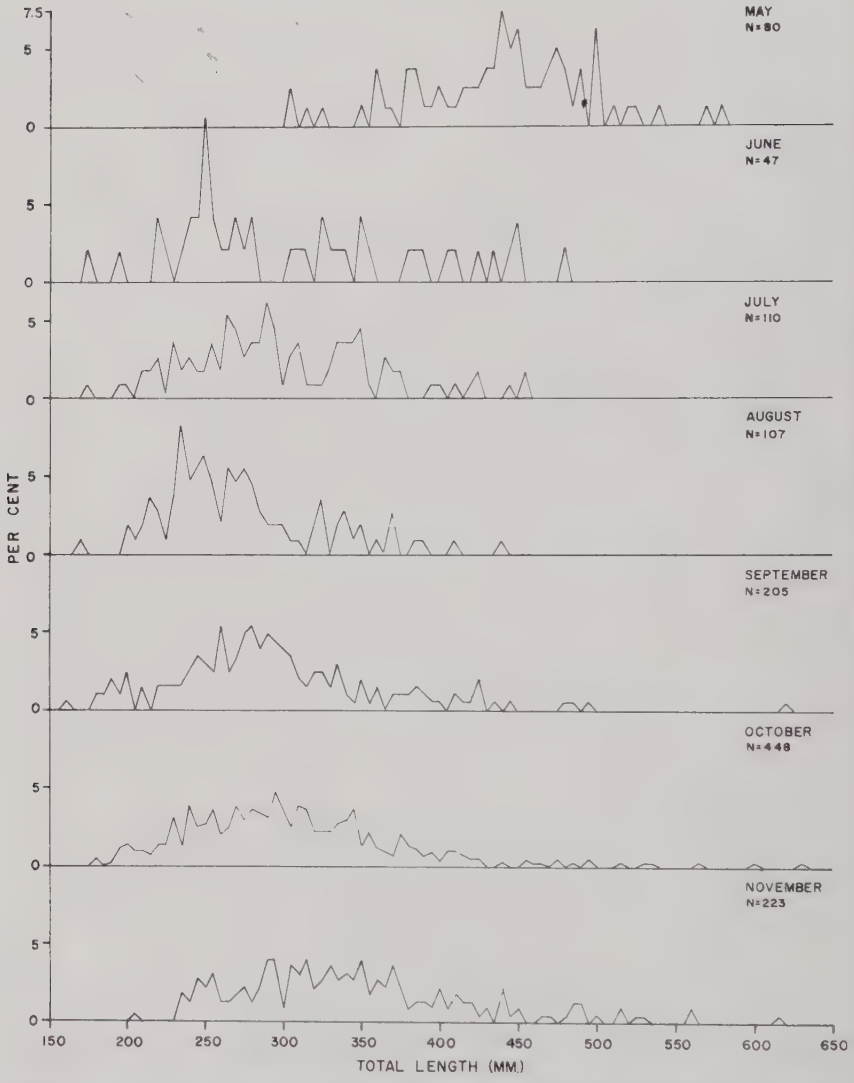

Figure 4. Monthly length-frequency distribution of tautog caught by sport fishermen in 1966.

May was characterized by low catches and catch rates, but the fish taken at that time were of large size. From June through August, catches and catch rates remained low and the smallest average sizes of tautog were recorded. In the fall, the highest catches and catch rates were attained and average sizes of the fish increased significantly.

Table 7. Average Total Length (in millimeters*) for Tautog Taken by Sport Fishermen Each Month

Year	May	June	July	August	September	October	November	Season
1964	419 (16.5)	264 (10.4)	245 (9.7)	261 (10.3)	318 (12.5)	333 (13.1)	309 (12.2)	308 (12.1)
1965	401 (15.8)	271 (10.7)	267 (10.5)	265 (10.4)	286 (11.3)	333 (13.1)	358 (14.1)	317 (12.5)
1966	439 (17.3)	310 (12.2)	299 (11.8)	273 (10.8)	294 (11.6)	304 (12.0)	342 (13.5)	315 (12.4)
Average	427 (16.8)	276 (10.9)	281 (11.1)	266 (10.5)	300 (11.8)	321 (12.6)	334 (13.2)	313 (12.3)

* Figures in parentheses are equivalents in inches.

Table 8. Analysis of Variance for Mean Lengths of Tautog Given in Table 7

Source of variation	Degrees of freedom	Sum of squares	Mean square	*F*	
				Value	Reference value*
Total	3,227	17,852,316			
Months	6	3,254,228	542,371.3	126.49	2.80
Years	2	42,132	21,066.0	4.91	4.60
Months vs. years interaction	12	804,284	67,023.7	15.63	2.18
Within subclasses	3,207	13,751,672	4,288.0		

* At 1 per cent level of probability.

TABLE 9. VALUES OF "*t*" FOR COMPARISONS, BETWEEN CONSECUTIVE MONTHS, OF DATA GIVEN IN TABLE 7

Year	May vs. June	June vs. July	July vs. August	August vs. September	September vs. October	October vs. November
1964	7.41**	1.26	1.12	7.58**	2.50	4.48**
1965	9.94**	0.43	0.13	1.86	7.53**	4.35**
1966	9.98**	0.96	2.93**	2.69**	1.81	7.08**
Average	20.96**	0.82	2.50	7.07**	6.16**	4.13**

** Significant at 1 per cent level (greater than "*t*" = 2.58).

While tautog were generally a prime objective of many anglers in the fall, the species usually played a supplementary role in the sport fisheries of eastern Long Island during the summer. Although they fished for tautog, the anglers would rather catch other species, scup for example. Indeed, it was observed that most anglers who fished for tautog in the summer did so only to augment their catches of other, more desired species. Tautog also were used as an alternative species by anglers aboard Greenport-based charter boats when the angling for bluefish and/or striped bass (*Roccus saxatilis*) was poorer than expected (Briggs, unpublished data). This situation was similar to that observed in the south shore bays of Long Island where winter flounder sustained the sport fisheries when angling for summer flounder was poor (Briggs, 1962, 1965).

These observations suggest that greater fishing effort could probably be exerted upon the tautog. Certainly in the summer, the catch, and perhaps catch per effort, would increase if tautog were sought as a prime objective rather than as a supplementary species. However, analysis of the sizes of tautog taken by anglers appears to indicate that large fish of the species are not available in the same numbers in summer as they are in the fall. It appears that tautog could sustain greater fishing effort on the grounds fished by Montauk Harbor-berthed open boats and charter boats, particularly in the fall when the catch rate for tautog is the highest.

At present, there are few sites available to anglers desirous of fishing for tautog from banks and piers. Creation of fishing piers in rocky areas, especially on Long Island Sound, would be a desirable asset to tautog angling, provided they were constructed in sufficiently deep water (at least 10 to 15 feet). In addition, improvement of launching facilities at Truman Beach would provide greater access for small boat anglers seeking tautog.

Table 10. Values of "*t*" for Comparisons, Between Same Months of Different Years, of Data Given in Table 7

Year	May	June	July	August	September	October	November	Total
1964 vs. 1965	0.78	0.74	1.46	0.34	4.60**	0.00	8.31**	3.08**
1964 vs. 1966	0.95	3.76**	3.71**	1.40	3.63**	6.00**	5.63**	2.52
1964 vs. 1966	2.74**	3.50**	3.29**	0.67	1.17	6.05**	2.56	0.71

** Significant at 1 per cent level (greater than "*t*" = 2.58).

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LACTIC ACID LEVELS IN ADULT LAKE TROUT IN CAYUGA LAKE, NEW YORK[1]

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ABSTRACT

The possibility of delayed mortality in fatigued lake trout following gill netting and tagging was investigated by determining blood lactic acid levels and by holding fish in pounds. Gill netting plus tagging raised lactic acid concentrations four-fold over the resting level but was not associated with increased mortality.

Large numbers of lake trout (*Salvelinus namaycush*) spawning at depths of 100-200 feet in Cayuga Lake are gill netted for the purpose of taking eggs and tagging. Tag returns are used in estimating exploitation and other vital statistics (Webster *et al.*, 1959), and the possibility of mortality attributable to the method of capture or marking procedure is of particular concern. Approximately 5 per cent of the fish netted are dead when the nets are lifted after being fished overnight. Mortality seems to increase during windy weather, probably due to increased velocity of lake currents. Dead trout have damaged gills or are entangled so that respiration is impaired. Most of the live trout appear in good condition following removal from the nets, but fatigue due to struggling in the nets and subsequent handling was considered a possible source of delayed mortality after the fish were released. An exploratory study was undertaken in 1960 to determine if netting and handling caused delayed mortality.

Lactic acid is produced as a result of muscular exercise (Black, 1958), and measurement of lactic acid concentrations in blood samples has been used as a measure of fatigue in fishes (Black, 1955, 1957, 1958; Black and Barrett, 1957; Parker and Black, 1959; Parker *et al.*, 1959). Lactic acid levels in lake trout were measured at various stages of the netting and tagging operation to evaluate the degree of fatigue to which fish were subjected.

MATERIALS AND METHODS

The Baker-Summerson method (Hawk *et al.*, 1954) was used to determine blood lactic acid concentrations. Sodium fluoride was used

[1]The study was suggested by Dr. D. A. Webster, Professor of Fishery Biology at Cornell University, and he also offered suggestions on the manuscript. Dr. J. L. Forney and Mr. W. D. Youngs also reviewed the manuscript. Dr. A. M. Phillips, Jr., U. S. Fish and Wildlife Service, Eastern Fish Nutrition Laboratory, Cortland, New York advised on chemical techniques. The study was financed in part by the New York State Conservation Department.

as an anticoagulant and trichloroacetic acid filtrates were used for the lactic acid determinations. Blood samples (2-4 milliliters) were drawn from the heart with a hypodermic syringe. Lactic acid levels were determined for lake trout:

(1) at rest,
(2) immediately after removal from a net,
(3) immediately after tagging,
(4) 2 to 2-½ hours after tagging.

The 12 fish used for analysis were adult trout 5 to 10 years old and 22 to 30 inches in length. The resting level of blood lactic acid was estimated using fish that had not been subjected to exercise or handling within 24 hours. These fish were gill netted on October 10, 1960 and retained for 2 days in a holding pound. The fish were then transferred to a raceway at the Cornell University Fishery Laboratory and held 6 days. Samples taken from three fish were used to approximate the resting level of blood lactate in spawning adult lake trout. Gill-netted trout were caught during their spawning season. As an additional check on delayed mortality, gill-netted trout were retained in a holding pound on several occasions. The pounds used measured a minimum of 12 x 16 x 8 feet and were placed on the bottom in 12 feet of water.

RESULTS

Netting and tagging caused a four-fold increase in lactic acid levels over the resting state (Table 1). An analysis of variance comparing netting levels and netting and tagging levels with resting levels showed a significant difference ($F = 10.07$ with 2 and 6 degrees of freedom). The highest values observed did not approach the mean blood lactate concentration of 177 milligrams per 100 milliliters of blood reported by Black (1957) for severely exercised 1½-year-old, hatchery-reared lake trout. In a later paper, Black (1958) reported that no mortality was observed in these fish. Thus, lake trout have survived much higher lactic acid levels than those encountered in the Cayuga Lake netting and tagging operations. It is possible, however, that the highest lactic acid levels in the Cayuga Lake fish occur some time after the fish become entangled in the nets, and the concentrations observed when the fish are removed from the nets may be lower because the fish are in a recovery stage. Black (1957) reported peak lactic acid levels 2 hours after severe exercise.

Only one fish died among 120 impounded for periods of from 6 hours to 6 days following netting and tagging. Black (1957, 1958) found no mortality in severely exercised lake trout. Parker *et al.* (1959) found that mortality from fatigue in Pacific salmon (*Oncor-*

TABLE 1. LACTIC ACID CONCENTRATIONS IN THE BLOOD OF LAKE TROUT FOLLOWING

Activity	Lactic acid concentration*	
	Individual fish	Mean
Resting	25.7 12.3 21.3	19.8
Netting	52.5 99.8 83.0	78.4
Netting and tagging	85.3 124.3 77.3	95.6
Two hours after netting and tagging	81.3 110.5 64.3	85.3

* In milligrams per 100 liters of blood.

hynchus sp.) was highest 2 to 3 hours following exercise and was negligible after 6 hours. Thus, it seems likely that any mortality caused by fatigue would have been apparent within the time intervals fish were held in the present study. The cursory data available seem adequate to support a conclusion that fatigue, in itself, is not an important factor in contributing to delayed mortality of adult lake trout handled in the fashion described.

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GENERAL NOTES

A LENGTH-WEIGHT RELATIONSHIP FOR TAUTOG FROM THE INSHORE WATERS OF EASTERN LONG ISLAND[1]

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During the period from May 1 through November 30 each year from 1964 to 1966, tautog *(Tautoga onitis)* were weighed and measured as part of a general survey of the sport fisheries for this species in eastern Long Island waters (Briggs, 1969). A total of 3,156 specimens, representing a sample of the catches landed

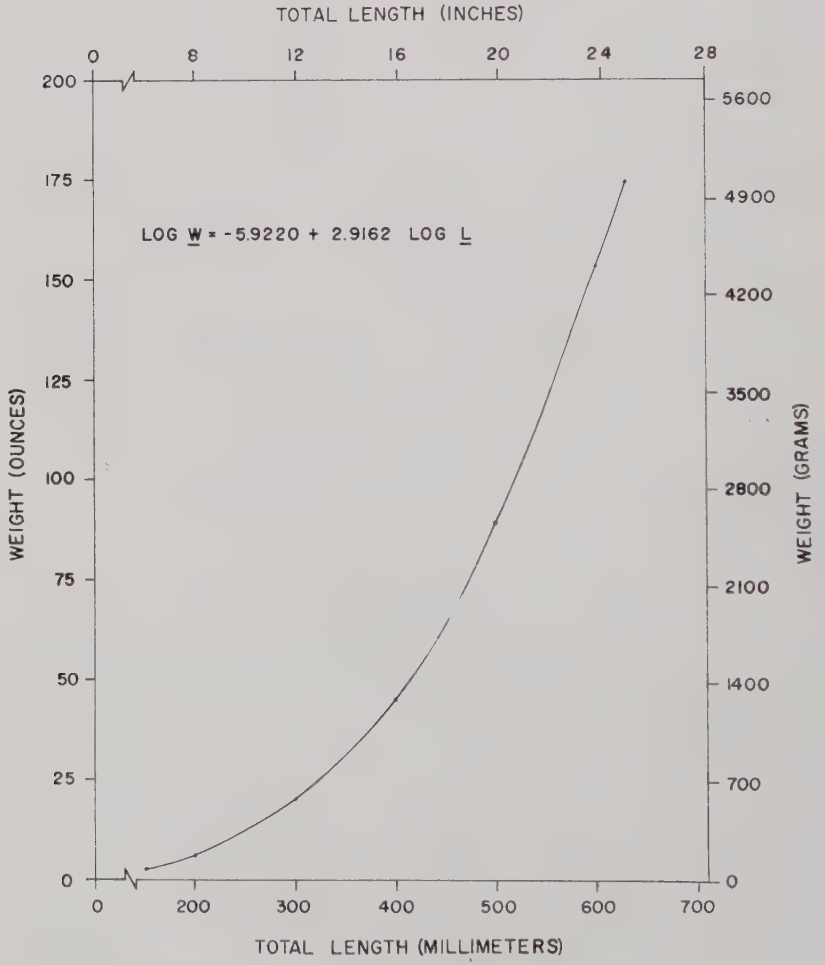

Figure 1. Length-weight relationship for tautog from the inshore waters of eastern Long Island.

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[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-15-R.

Table 1. Calculated Weights of Tautog at 25-millimeter (1.0 inch) Intervals

Total length		Calculated weight	
Millimeters	Inches	Grams	Ounces
150*	5.9	76.5	2.7
175	6.9	119.1	4.2
200	7.9	172.9	6.1
225	8.9	246.6	8.7
250	9.8	334.5	11.8
275	10.8	439.4	15.5
300	11.8	567.0	20.0
325	12.8	717.3	25.3
350	13.8	890.2	31.4
375	14.8	1,088.6	38.4
400	15.8	1,315.4	46.4
425	16.7	1,567.8	55.3
450	17.7	1,854.1	65.4
475	18.7	2,168.8	76.5
500	19.7	2,520.3	88.9
525	20.7	2,905.9	102.5
550	21.7	3,328.3	117.4
575	22.6	3,787.6	133.6
600	23.6	4,289.4	151.3
625	24.6	4,830.8	170.4
630*	24.8	4,941.4	174.3

* Smallest and largest tautog measured.

by sport fishermen at rowboat stations at New Suffolk, Southold and Orient Point, were weighed to the nearest ounce (28.3 grams) and measured to the nearest 5 millimeters (0.2 inch).

A length-weight relationship was calculated from the data using the method of least squares. The resultant formula, $\log W = -5.9920 + 2.9162 \log L$, where W is the weight in ounces and L is the total length in millimeters, is presented graphically in Figure 1. Calculated weights at 25-millimeter (1.0 inch) intervals are given in Table 1.

These data differ from the length-weight relationships published by Cooper (1967) in that his formulae were derived from sexed and eviscerated fish collected in one month (June 1961), while the present formula was derived from unsexed and uneviscerated fish collected from May through November over a 3-year period.

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NATIONAL FAST TURQUOISE KS LIQUID AS A LONG TERM DYE MARK[1]

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National Fast Turquoise KS Liquid[2] is chemically related to National Fast Blue 8GXM[2]. Both are cationic dyes prepared from a copper phthalo cyanine nucleus. Both dyes produce a bright blue mark when injected or tattooed, and both have a tendency to migrate.

Marks made by National Fast Blue 8GXM have remained visible after weight gains of 200 per cent in trout 7 inches long when injected and after gains of up to 700 per cent in trout injected as fingerlings. Injection has been successful in many areas including the lower jaw and cheek (Loeb, 1968). In the latter area diffusion produces a large blue mark. Diffusion has also been illustrated by quick appearance of the dye in abrasions an inch from tattoo marks that had just been made.

National Fast Turquoise KS Liquid forms a more brillant mark and diffuses to a much greater extent; the dye was found in the fins and body musculature of one fish dissected immediately after injection, although most of the dye remained in the injected area. The dye is more water soluble than National Fast Blue 8GXM and is quite stable at high pH and temperature. Data on toxicity are limited; three trout in 20 died after presumed overdosage.[1]

Twenty brown trout *(Salmo trutta)* averaging 84 grams in weight were cheek injected with KS Liquid and held for observation at 47° F. When the test was inadvertently terminated at 8 months all marks were brilliant. Weight had increased 151 per cent as against 154 per cent for control fish. Dissection of several fish showed no dye in other than cheek-area tissues; dye dispersed from the site of injection had disappeared during the test. Comparison with numerous tests using National Fast Blue 8GXM indicates that the undispersed portion of a KS mark would last for a long time over a greater increase in growth. Of the two dyes, the KS Liquid provides a brighter and probably more durable mark.

LITERATURE CITED

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[1]A contribution of Federal Aid in Fish and Wildlife Restoration Project F-9-R.
[2]Manufactured by Allied Chemical Company.
[3]Allied Chemical Company, personal communication.

The work reported here was strictly a laboratory study. A drug or chemical may not be used on fish that may later be consumed as food unless such drug or chemical has been approved by the Federal Drug Administration. — Editor.

TWIN FAWNS BORN TWO DAYS APART

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A group of white-tailed deer (*Odocoileus virginianus*) kept in pens at the Wildlife Research Laboratory at Delmar (N.Y.) includes some white-coated animals. These are being used, with typical brown-coated animals, in cross-breeding experiments to provide information concerning the genetics of a population at the Seneca Army Depot in central New York in which white-coated deer predominate. In the fall of 1967, several brown-coated does were bred to a white-coated buck. One of these does gave birth during the night of July 7, 1968 to a brown male fawn weighing 7¼ pounds, and during the early morning of July 9, 1968 the same doe gave birth to a white fawn weighing 6 pounds. Both fawns were in good condition. Whether this was a case of superfetation or superfecundation, or whether some abnormality occurred at parturition preventing normal delivery of the second fetus, is unknown.

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